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Characterisation of view relative to solar-control systems

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A B S T R A C T

Solar shading can be an effective way of avoiding overheating by reducing solar gains in buildings. However, solar shading systems can block or obscure the view-out with the consequence that occupants may refrain from using the shading system. As such, there is a need to quantify the effects of shading on occupants' perception of the view.

In this study, we developed a method to identify the photometric parameters and compositions that are effective in characterising the view-out in relation to different solar-control systems. We hypothesized that the photometric composition, e.g., contrast, in the visual environment as a result of using solar-control systems impacts the subjective assessment of the view. We conducted objective photometric measurements using calibrated luminance cameras and subjective responses from 64 participants in a semi-controlled work environment to test the hypotheses. The participants were randomly allocated to a combination of five view-outs and six solar shading systems in a work environment where they answered questions related to the indoor environment and view quality. The relation between view and solar-control systems and their impact on the subjective view assessment was tested using linear mixed-effects models. The models were developed using forward and backward selection based on AIC and likelihood ratio tests (LRT) to test the effects of adding or removing variables. The achromatic contrast calculated based on the measured luminance data both locally and globally was significantly associated with view assessment and satisfaction when using different shading types.

1. Introduction

In response to the growing emphasis on energy efficiency and indoor environmental quality in buildings, there has been an increase in interest in solar shading. This heightened interest has led to the development of numerous innovative shading solutions [1] that mainly aim to reduce excessive solar gains and ensure optimal thermal and visual comfort within buildings. However, research indicates that visual discomfort [2–4], and high levels of light intensity at the eye level [5] are often tolerated in the presence of view outside. Moreover, there are interactions between the presence of daylight and view with perception and acceptance of thermal conditions [6]. Furthermore, studies have demonstrated the positive impact of views on physiological and psychological comfort [7], occupants' well-being [8], visual quality of the space [9], and specific operational scenarios [10]. Therefore, the careful choice of shading devices, combined with other fenestration components, is pivotal for maximizing energy efficiency and enhancing the overall well-being and comfort of the building's occupants.

The assessment of shading devices can be approached from multiple perspectives, considering design parameters, technology, positioning, control mechanisms, as well as their ability to reduce solar gain and glare [1,11]. While quantitative parameters enable the direct measurement of energy efficiency, thermal comfort performance [12], and glare reduction [13] by shading devices, the relationship between these factors and the view-out has received limited attention. The existing standard, *EN 14501* [12], recommends a method based on the normal/normal visual transmittance ($\tau_{v,\ n\text{-}n}$) and diffuse part of the light transmittance ($\tau_{v,\ n\text{-}dif}$) for "view contact" evaluation for shutters and blinds. Although the proposed method allows for an assessment of the view when shading devices are deployed, it may not thoroughly consider variations in photometric compositions, such as contrast and color contrast, or the "interruptions" to the view context that can vary greatly depending on the type of shading device. The lack of tangible visual quality measures for shading devices is evident in the new recommendations for the view out in *EN 17037:2018 Daylight in buildings* [14] under the *CEN/TC 169 "Light and Lighting"* scope. The mentioned standard defines requirements for the content and view access through the windows to ensure the quality of the visual environment. The standard offers geometrical stratification methods and an image-based method. In either case, if the minimum level is followed, it is ensured

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that "*All occupants of a space should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus*" [14], which can be difficult to translate when shading is deployed. Enhancing the performance of shading devices for higher view quality in this context can improve their overall effectiveness as part of fenestration systems. Understanding the effect of shading devices on view may help to select shading devices that are used appropriately by the occupants and could serve as a step for better incorporating them in view analysis methods [15].

Various hypotheses can be developed to explore how the perception of views is influenced by solar control systems and their components such as the shading, the glazing type, the window size, the sill depths, and their combinations. To characterize view-out relative to shading devices, however, it is essential to consider the inherent aspects of view quality itself. The quality of the view-out is influenced by several parameters and there is an ongoing endeavor to quantify and formulate its effect [9,16]. One way of approaching view quality is to categorize it into view content, view access, and view clarity [17]. The view content is the visual features seen through the window view including static features greenery or buildings, traffic, sky, and ground, and dynamic features e.g. spectral distribution or seasons [17]. The distance to the features will also influence the view content [9,16]. In general, it is preferred for occupants to have the content positioned farther away from their eyes [9,17,18], which allows the muscles of the eyes to relax and provides a more expansive view. Among the static view features studies have shown that natural features, such as greenery and water, are preferred over urban or built features, although landmarks and aesthetic architecture can also be desirable [19]. On the same note, urban views containing greenery will increase its attractiveness. Likewise, water will make both natural and urban scenes more desirable [18]. The complex composition of the view content, namely complexity, has also been addressed by other studies [20,21]. Heaps and Handel 1999 [22] define the complexity of an image as the difficulty of verbally describing the content. The perceptual dimensions of visual complexity were found to be various attributes such as the number of objects, clutter, openness, symmetry, organization, variety, and colors [20] while luminance-based quantification can be used to evaluate the complexity via sharpness and visibility of the shape and details of real 3-Dimensional objects observed by people [21]. In the later study, among the three luminance measures – the luminance ratio, mean luminance and standard deviation – they showed that the standard deviation of the luminance values calculated using Root Mean Square (RMS) correlates best with the perception of visibility. When using the RMS, the luminance of each pixel in the image is compared to the mean luminance of all pixels as an indication of the variability between different pixels. Considering the importance of view content on the perception of the view, the quality of the view through shading devices and its dependence on the content of the view should be addressed. Among different proposed methods for analysis and assessment of view content, the daylighting standard recommends accessing three layers of ground, landscape, and sky and proposes geometrical methods for angular access assessments [14]. Another earlier method for view content analysis was introduced by Hellinga and Hordijk [18] based on a scoring system scheme with questions about the content of the view to calculate a view quality rating (VQR), which is not fully validated [23].

View access is a measure of how much view an occupant has access to from a specific position and is particularly dependent on the geometric relationship between the view opening and the occupant [17]. Several different measures can evaluate the access of view. Therefore, a great variation is seen in requirements for view access in different standards [8,19]. Mardaljevic [24] advanced the geometrical stratification method along with luminance intensity by introducing the view-lumen method, which quantifies the illumination received at the building aperture from a visible external entity. Other available methods could use raytracing [25] to quantify the accessibility level of view and complexity. The methods mentioned could be used together with the shading devices; however, they do not provide information about the content and access, or their complex compositions, respectively.

Despite numerous methods for assessing view quality [9,18], the characterisation of view relative to solar control systems is less addressed. A shading device in most cases affects the view clarity. View clarity is an aspect of window view that addresses how clear, i.e., without distortion, a view-out is perceived by an occupant; thus, it depends on the properties and design of the window and any obstructions of view [17]. Some methods with limited application have used the openness factor and the visible light transmittance as measures for quantifying clarity [26]. Other methods recommend looking at visual acuity, contrast, and colour perception [17]. While visual acuity is more of an inherent visual characteristic [27], the variation in photometric compositions in the field of view has been shown traditionally to affect both visibility [28] and comfort [29]. Visual contrast sensitivity quantifies the amount of contrast the vision needs to discern shapes and objects [27]. There are various ways to quantify contrast in the field of view (FOV). The first measure for contrast was The Michelson contrast, developed in the second half of the 20th century [30]. This contrast is a global contrast where only the deviation between the maximum and minimum luminance of the entire field of view was considered. Pavel et al. [31] introduce the usage of RMS for deriving global contrast. Since global contrasts consider the whole FOV and not the contrasts between a source and its surroundings, other local metrics have been developed for this purpose. Rizzi et al. [32] developed the RAMMG algorithm, a local contrast measure used on images. In this algorithm, the mean contrast for different pixel levels by the local contrast of each pixel and its eight surrounding pixels is found. Local contrast algorithms hence seem closer to human perception of the visual environment as they can easily identify differences in luminous intensity of pixels beside each other than far away from each other. This method has been shown to correlate best to visual perception of different visual compositions in a daylit environment [33]. Glare is another representation of contrast where the unbalanced levels of light [34] create negative subjective responses. Several glare models [35] based on contrast and visibility models have been developed to address this phenomenon. What is clear is that the photometric compositions in the FOV have hence been shown as indicators of subjective assessments of the visual environment.

In this study, we used both the methods provided in the daylighting in buildings standard and the VQR method to identify view content classifications, we later used the RMS method for quantification of the complexity of the view conditions as shown in Fig. 2. We hypothesize that the photometric composition of the combined shading and view, measured using complexity or contrast algorithms, influences the perception of the view and hence can be used as a measure to characterize the view in relation to the shading devices. This hypothesis was tested in an experimental study that employed both objective and subjective measurements to identify the key parameters affecting the view-out in relation to shading devices. The experimental setup focused on daylit spaces with no electric lights on. The photometric composition was defined as a series of relations between photometric quantities to describe perceived complexity [21] and perceived contrast [32] in the field of view. To characterize the view based on its photometric compositions, we tested three initial hypotheses – see Fig. 1. The photometric composition of the view through shading can be affected by all three different aspects of view quality as we know them now.

With the first hypothesis, the aim was to explore how the light levels and their relation as measured in photometric values perceived at the eye affect the quality of view and if any of the identified relations as shown Table 1 best describe the subjective assessments. The second hypothesis should help clarify the impact of commonly used Solar shading types (SST) on the view-out quality. Here only the design parameters of the different SSTs were in focus. With the third hypothesis, it was desired to investigate how the interruption of the *amount of view* by the slats, quantified based on the characteristics of the shading (i.e., the slat angles, the slat direction – horizontal or vertical, and the number of

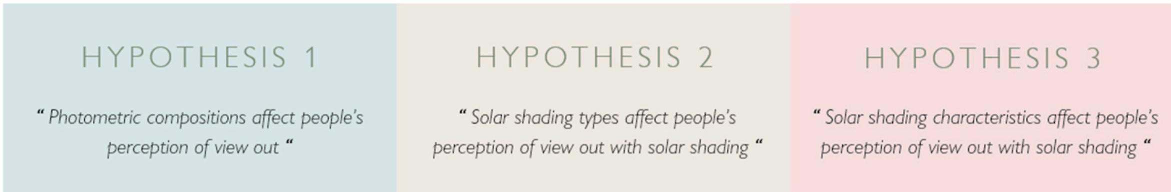

Fig. 1. The three hypotheses investigated in this work.

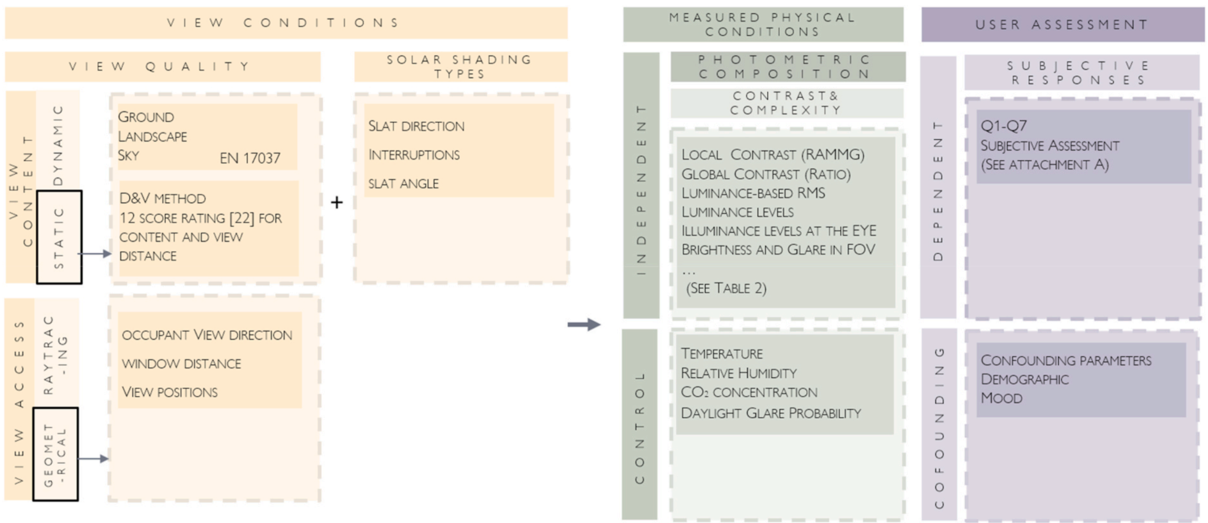

Fig. 2. A schematic showing the selected aspect of view quality that has shaped the experimentation strategy in this study.

Table 1
The description of the photometric quantities by Evalglare.

No	abbreviation	Description	Platform	ref
1	BS_No	Number of detected bright sources	a	
2	BS_Avg_L	The average luminance of all bright source	a	
3	BS_Max_L	The maximum luminance of the brightest source	a	
4	L_b	The luminance of undetected pixels as bright	a	
5	L_a	Average luminance	a	
6	BS_E	Illuminance of bright sources	a	
7	Vert_E	The illuminance of undetected pixels as bright	a	
8	DGP	Daylight glare probability	a	[44]
9	GI	Glare impact based on the contrast part of the glare formula	a	[45]
10	GC	The ratio between BS_Avg_L and Lb	a	
11	RMS	The standard deviation of the luminance values		[21]
12	RAMMG	Contrast algorithm		

[a] Calculated in MATLAB using the initially derived quantities in Evalglare.
[a] Calculation by internal Evalglare Algorithms.

interruptions), affected the occupants' view perception. Across all three hypotheses, photometric parameters as possible indicators for the view-out quality through the shading devices were tested. These parameters as well as the distance to the window were calculated based on measurements from each participants view position and view direction in relation to the window.

2. Methodology

The drawn hypotheses were tested in a series of user assessment experiments. The view conditions were considered based on view content and view access definitions in the EN 17037 and D& V methods. Concretely, we selected rooms across available office rooms that would be examples of "low-quality view "and “high-quality view” in terms of view content. And a variety of accessibility by changing view positions and distance to the window. Fig. 2 draws a schematic behind the experimental set up. Physical conditions in each setting were measured in terms of indoor temperature, relative humidity, and CO_2. The photometric compassions were calculated based on measured image-based luminance values. A series of user assessment studies were done in 2 months in autumn and 64 samples were selected. The details of the experimental setup and trials are explained in the following sections.

The study was done in a semi-controlled environment where participants took part in a 1-and-a-half-hour user-assessment experiment. The experiments took place in four meeting rooms in two different buildings at the Technical University of Denmark between October 25th, 2021, and November 22nd, 2021. The participants were randomly assigned to different view conditions, and their corresponding subjective responses were recorded. Each trial involved five participants seated at various distances and view positions either parallel or perpendicular with respect to the window which allowed various view conditions in the field of view (FOV). Each participant experienced all the view and shading conditions from their assigned view position in each two rooms.

2.1. View conditions

Fig. 3 shows the four rooms that were selected for the study. Rooms A and B were identical office/meeting rooms with a distant view-out featuring a combination of greenery and artifacts. Room C featured views with smaller angular access to the sky and greenery blocked by an opposite building. n rooms A, B, and C, 5 view positions were considered which meant 5 different view content in the field of view of the participant. To expand the view conditions towards lower quality views with even lower angular access to sky and greenery we chose Room D.

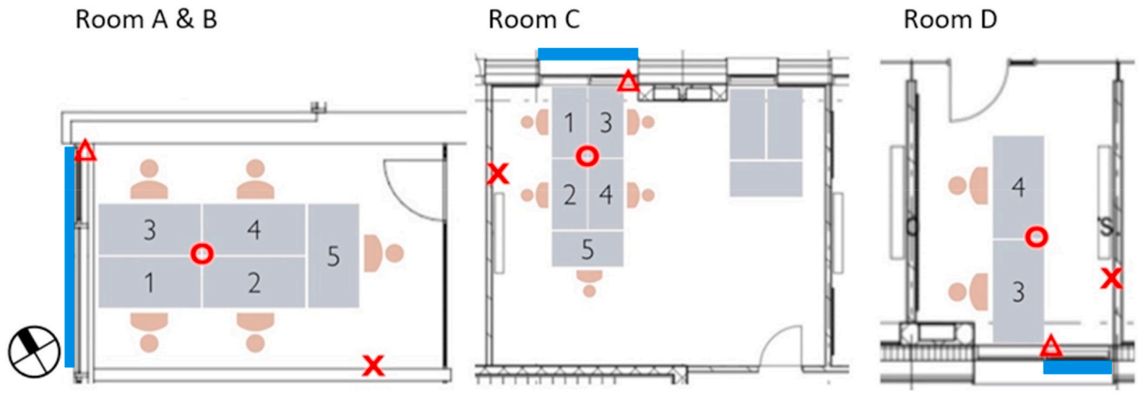

Fig. 3. The layout of the four rooms and the measurement points are shown. Rooms A & B had a similar layout. The blue line highlights the window with the view-out. The symbol **Δ** shows the placement of the illuminance meter at the window. The symbol **O** depicts the illuminance meter at the horizontal level, and the symbol **X** marks the location of the temperature, relative humidity and CO2 sensors. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

However, only two positions could be considered in this room. Rooms D & C were both in the same building and similar in terms of the interior visual environment, i.e., window size, surface colors, and materials, and minor differences between the two rooms. Room D could accommodate only 2 participants, as can be seen in Fig. 3, where part of the view is obstructed by an overhang corridor between two buildings, hence creating a lower view quality. In experimental rounds with the worst view, we used view positions 3 & and 4 in room D. To keep the experimental procedure consistent, we used positions 1, 2, and 5 in Room C w to accommodate 5 participants. In these trials, we limited the angular access to greenery in room C by blocking the view using garbage containers which were placed outside the window to partially block the view. Throughout the experiments, in rooms A and B, the view-out conditions were altered by using vertical and horizontal external mock-ups and the existing external Venetian blind with grey slats creating in total of 5 view-out conditions in each room. In rooms C and D, the existing external horizontal Venetian blinds with black slats were controlled by adjusting the angles. Moreover, 10 view conditions were created by adjustment of the slat angles across the two rooms. Using the Quality Rating method, the “view quality” of each room was assessed based on the Hellinga et al. method [18] (see Appendix B).

2.2. Shading devices

All rooms were equipped with Venetian blinds. The existing Venetian blinds in rooms A & B were with grey slats and in rooms C & D with black slats. In rooms A & B, it was possible to extract and detract the shadings with limited slat angle changes. However, the blinds in rooms C & D allowed for slat angle adjustment with larger angular steps. Four mock-ups of commonly used external SSTs were made. The dimensions of the slats were chosen based on existing products from Blendex, a local provider. Mock-ups of the external shading devices were positioned outside the windows, allowing for random switching between different types of shading in a randomized sequence. The layout of the rooms and the positions of the participants are illustrated in Fig. 3, with each participant’s position shown by a number. Figs. 4 and 5 display the different shading types as observed from the participants’ five seating positions and view directions in the different rooms. The small and big slats were 8 mm and 18 mm in thickness respectively with 80 mm and 200 mm in width and were semi-glossed to enable some light reflection without creating glare (RAL 7022).

In total six different shading types were tested namely, Big Horizontal (BH) slats, Big Vertical (BV) slats, Existing Venetian blinds in Black (EX_B), Existing Venetian Blinds in grey (EX_G), Small Horizontal (SH) slats, Small Vertical (SV) slats. More details about the mock-up can be seen in Ref. [36].

2.3. Experimental protocol

To account for potential influences from other indoor environmental variables, measurements of temperature, CO_2 concentration, relative humidity, and light levels were taken at 10-s intervals. Additionally, observations were made regarding weather, noise, and changes in the view (the outside scene). Finally, the artificial lights were turned off during the experiment. To ensure the consistency of the experimental procedure, a checklist was provided and strictly followed throughout the experimental period. The experiments were performed by two observers. Participants arrived at the rooms where they were informed beforehand. They received an introduction and instructions before the experiment began. The Participants started by sitting at assigned tables in one room and answering questions. They accessed the questionnaire through a link that they were provided and went through the questions using their own laptop screens. When all 5 participants finished with the demographic part of the questionnaire, the first round started, where they would answer the questions for the first view condition. Each round took 2–3 min. After each round, observer 1 instructed the participants to move to the hallway with their laptops. This short transition allowed for visual readaptation to the environment. Afterwards, the participants moved to the second room. Meanwhile, image-resolved photometer measurements were taken at each view position by observer 2 to capture the daylit conditions as close to those observed by the participants. While the participants were in the second room, the first room was adjusted with the next randomly selected shading conditions for the next round. After the first 6 rounds (3 in each room), participants had a 10-min break and then continued with 6 more rounds following the same procedure. Each trial took around 1.5 h to complete.

2.4. Questionnaire

Subjective responses were collected using an on-screen questionnaire that involved multiple questions answered on continuous scales. The questionnaire was split into two parts – The first part contained demographic information, and the second part contained the evaluation of the view conditions. The questionnaire was developed using the "Guide to Good Questionnaires" [37]. All questions had a simple structure and were formulated clearly. To accommodate the on-screen work environment, the questionnaire was answered online [38] on the participants’ laptops. A continuous scale from 0 to 100 was used throughout for acceptability and satisfaction assessments of the view and the shading devices. The questionnaires were prepared in English and Danish and double-checked by expert native speakers of both languages to ensure accurate interpretation.

In the first part, the participants were asked about their eye

Fig. 4. Cropped Fisheye images from each position showing the each window view condition through different solar shading.

conditions, eye corrections, colour blindness, and contrast sensitivity. Moreover, the participants' physical well-being and mood were asked in this part. The second part of the questionnaire contained a total of 8 questions related to view assessment and satisfaction from the view of the solar shadings. The first three questions, Q1- Q3, were asked in all conditions. In this paper, we explored the photometric compositions in relation to Q1 & Q3 as shown in Fig. 6. In *Q.1.* the participants rated the view on a 0–100 scale from terrible to excellent. In *Q.3.* the participants rated the view on a 0–100 scale from very unsatisfying to very satisfying as shown in Fig. 6.

2.5. Measurements and photometric parameters

Fig. 7 shows all the equipment used in the experiments. The pieces of equipment were positioned in each room as shown in Fig. 3. Two image-resolved photometers were used to capture photometric quantities. Fig. 7a and b show respectively the LMK 6–12 CMOS from Techno Team with a fisheye lens offering hemispherical FOV of 167°, and a step-by-stepv [39] self-calibrated [40,41] Digital-single, Len-Reflect (DSLR) Canon EOS 5D Mark II camera with an 8 mm Sigma f/3.5 fisheye lens was used to take multi-exposure LDR images. The high dynamic range (HDR) luminance images taken with the light-measuring video photometer LMK were captured using Labsoft [42]. To process the images several Radiance-based tools were used [43]. The images were then converted to the Radiance PIC file. format using a tool called *pftopic.* The images were reprojected from their original equi-solid angle to an equi-angle projection using *pcomb* and reduced to a resolution of 1200x1200 pixels using *pfilt.* The images were then processed with *Evalglare v. 2.09* [44–46] to calculate the relevant photometric parameters. The LDR images taken with the DSLR camera were set up using "qDslrDashboard" software to take 15 JPG images at different exposure times. To get these LDR images ready to be used in Radiance they were

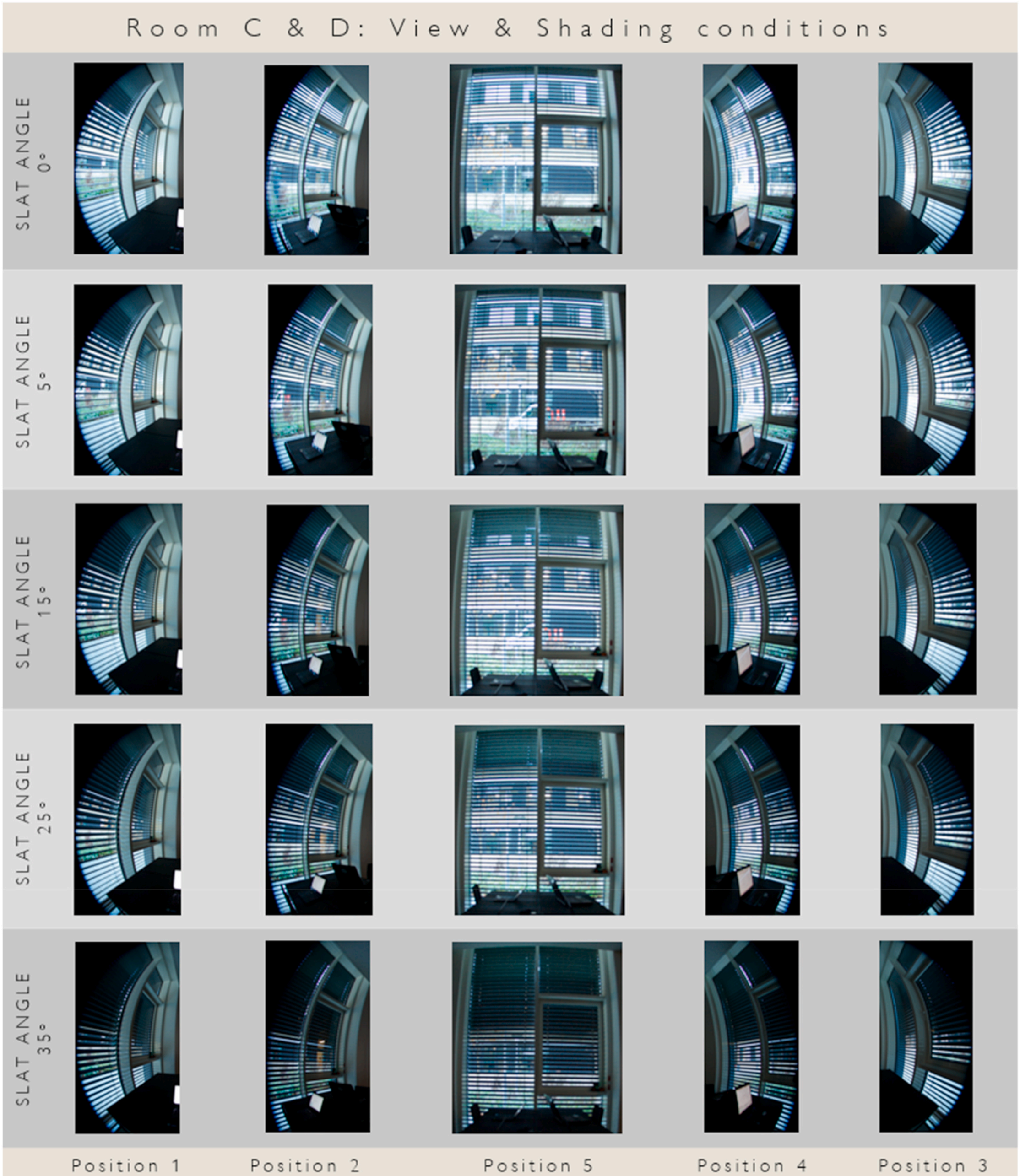

Fig. 5. Cropped Fisheye images from each position showing the each window view condition through different solar shading in room C. The shading conditions were identical in room D but the view was different.

Fig. 6. Q.1 & Q.3 as displayed in the questionnaires with a slide bar.

converted into HDR images using the Radiance-based tool *HDRgen.* The obtained HDR images were then processed similarly to the LMK images using *Evalglare*. The algorithm in the tool allows for the detection of bright pixels above a threshold here set at 2000 cd/m^2 and based on a predefined search radius, identifies pixels of the bright sources (BS_no) in the scene. Moreover, the average luminance (L_a) weighted by pixel size ($\omega_{s)}$, and illuminance of the scene (E_v) defined as the cosine projection of each pixel dependent on the pixel size were derived. Table 1

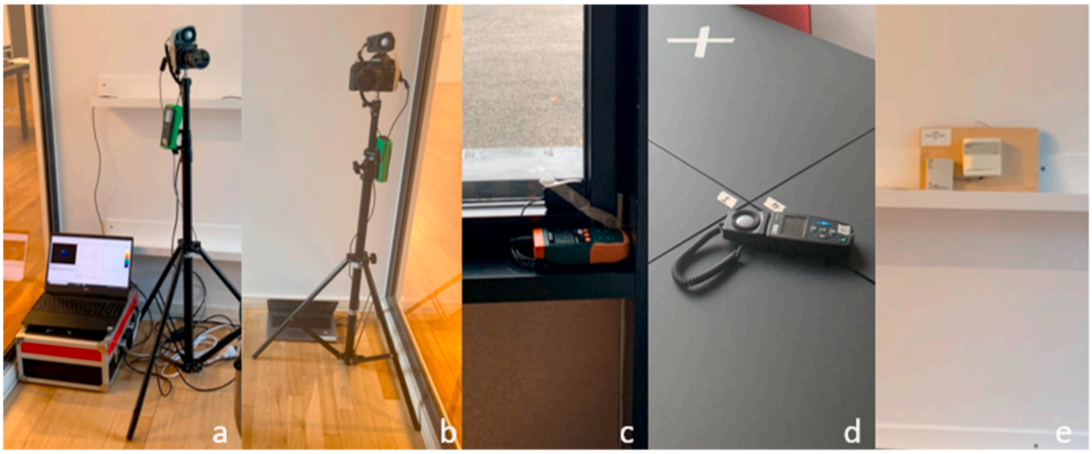

Fig. 7. Photos of the equipment. a) LMK image-resolved photometer equipped with lux meter for control, b) home-calibrated Canon image-resolved photometer equipped with luxmeter, c) vertical illuminance lux meter at the window, d) horizontal luminance lux meter at the table, and e) HOBO together with VAISALA indoor measurement station.

shows the obtained and calculated photometric parameters retrieved from each luminance image where *Evalglare* and *Matlab* were used as the main calculation tools. Both cameras were mounted on a tripod for them to be easily maneuverable in the rooms and one image was taken from each participant's position for each view-out condition. The luxmeters were placed with the sensor in the same direction and as near to the lens as possible, allowing for two measurements of vertical illuminance. Due to the complicated processing procedure for the canon images, some of the images were lost. In total out of 749 captured images 617 measured conditions were obtained. To capture contrast perception and complexity of the scenes achromatic RAMMG or in general terms local contrast [32] and achromatic RMS or in general terms complexity [21] were derived using MATLAB 2019. Images were read into MATLAB using the *HDRread* command. The images were then transferred to CIE Lab [47] colour space using the MATLAB *rgb2lab* command for these calculations. RAMMG was derived based on a 6-level subsampling of the images for contrast using a MATLAB code. Table 1 shows all the photometric parameters that were derived as independent variables that characterize the visual environment related to each view condition.

The temperature and the relative humidity of the air (RH) were measured using the Onset HOBO data logger, with an accuracy of ±0.53 °C from 0 to 50 °C and ±3.5 % RH from 25 to 85 % RH over the range of 15–45 °C. The CO_2 concentration was measured using the VAISALA CMD20 CO_2 monitor with an accuracy of ±2 % in the range from 0 to 2000 ppm. The equipment was placed at the wall at a height of 1 m near the occupied zone in the rooms. The parameters were measured and logged every 10 s, except for the first day of experiment B on the 25th of October, where the data was measured every 60 s. The measurements confirmed that the indoor temperature and air quality complied with the requirements for the indoor environment category II according to EN 16798:2019 [48].

Table 2 shows the time of the experiments and the sky conditions during the experiments. Only on two occasions did we have clear sky conditions, in the late afternoon. We objectively quantify the contrast through measurements, reflecting the contrast variations in the field of view under all sky conditions. No glare condition was detected at the participant's eye level from each point of view in any of the instances with daylight glare probability (DGP) in all cases below 0.25 as calculated by *Evalglare*.

2.6. Thermal environment and air quality

In all experiments, the temperature and CO_2 concentration were within the comfort range for all rooms. The mean temperature during the exposures varied between 20.5 °C and 22.5 °C. The mean relative humidity was between 34 % and 46 % and the CO_2 concentration was below 850 ppm in all experiments.

2.7. Participants

In total 64 subjective responses were accumulated by 51 participants, 13 of whom assessed all four rooms resulting in 64 data points. The demographic part of the questionnaire included questions about physical health, eye conditions, and mood. As the participants' IDs were changed for the 13 participants that participated in all rooms, here we report the instances of cases out of the 64 collected data. The gender distribution of the cases was 27 female and 36 male and one reported as others. In 61 cases the participants were in the age group between 20 and 30, in 2 cases between 30 and 40, and 1 instance above 50 years old. The participants were in general in good health and mood. The number of cases reporting excellent, good, and ok health are shown in Fig. 8. Only in one case bad physical health is reported. In 33 of the cases participants reported tiredness to some extent, while in most cases, no eye irritation was reported despite 18 cases of self-reported sensitivity to brightness. In 35 cases the participants reported near-sightedness and in 8 cases farsightedness and 42 cases the participants were wearing contact lenses through the experiments and one case of glasses. Other eye conditions were 3 cases of astigmatism and one case of colour blindness.

2.8. Analysis methods

Associations between subjective responses (SR) and photometric

Table 2
Overview of the date and time of the day that the experiments rooms A&B and C&D took place.

	Oct 25th	Oct 29th	Nov 1st	Nov 4th	Nov 5th	Nov 6th	Nov 22nd
Forenoon	Room A&B			Room C&D	Room C&D	Room C&D	Room A&B
Afternoon	Room A&B		Room A&B	Room C&D	Room C&D	Room C&D	
Late afternoon	Room A&B	Room A&B	Room A&B				
Sky Conditions	Intermediate	Clear sky	Overcast	Overcast	Overcast sky with the sun at the end	Overcast	Clear sky

Fig. 8. The number of cases on each scale point is shown, a) physical well-being, mood, and tiredness, and b) eye health in terms of sensitivity to brightness and eye irritation.

variables were inferred using linear mixed effects with random intercepts, expressed in equation (1). Models with random slopes were not possible due to a lack of data. The analysis was made in the statistical computing software R [49], using lme4 [50]:

$$SR \sim \text{Contextual variable}_{F} + \text{Contextual variable1}_{F} + \ldots + \text{Contextual variable n}_{F} + \text{Photometric variable}_{F} + \text{Photometric variable1}_{F} + \ldots + \text{Photometric variable n}_{F} + \text{Participant}_{R} + \varepsilon \quad (1)$$

Index F denotes the model's explanatory variables selected as fixed effects, while index R signifies the random effect. From this general expression, the best-fitting models were found for the responses to the questions *Q.1: Assessment of view-out* and *Q.3: Satisfaction with the view-out*. Selection of variables was made using forward and backward selection based on the Bayesian information criterion (BIC) [51]. The variable selection improved the BIC. A Likelihood ratio test (LRT) [51] was used to test the statistical significance level of each variable in the derived model. For hypothesis 1, only the view-out was investigated, i.e., all view conditions were without solar shading. Hypothesis 2 explored the effect of solar shading types (SST) on view assessment and satisfaction of view. Hypothesis 3 explored whether the interruption of view affected the participants' view assessment and satisfaction with the view. The interruptions to the view were defined based on the slat direction being horizontal or vertical, the distance between the slats which resulted in few or many interruptions, and the slat angle which was set to 5 fixed angular positions of 0, 5, 10, 25, and 35. To test hypotheses 2 and 3 only data with deployed solar shading was used.

3. Results

In our initial analysis, we observed that no immediate relationship was found between the mean subjective assessment and VQR as shown in Fig. 9, hence this parameter was not used in the further analysis in this paper.

3.1. Hypothesis 1

To test hypothesis 1, only view conditions without solar shading were considered to test how the photometric compositions of different views affected the subjective responses. In addition to the parameters defined in Table 1, we tested the "Window Distance". Equations (2) and (3) show the models with the lowest BIC for Q1 and Q3. Here the type of independent variables was continuous.

$$Q.1 \sim \text{Window Distance} + BS\_No + BS\_Avg\_L + \text{Participant}_{R} \quad (2)$$

$$Q.3 \sim GI_{F} + \text{Participant}_{R} \quad (3)$$

Table 3 shows the intercept and the coefficients for the fixed effects in Model (2). Of the three variables, only the BS_No had a significant

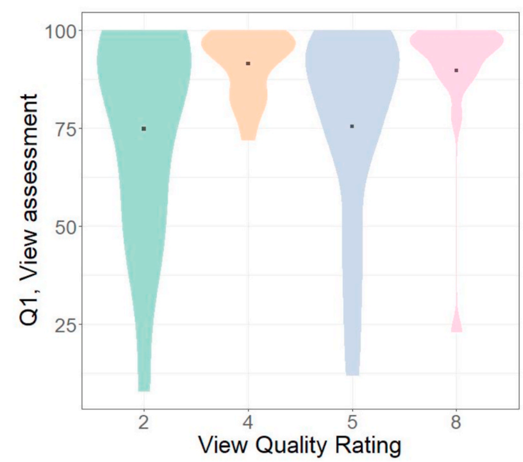

Fig. 9. Mean of all responses for Q1 given for all view conditions without shading, compared with the VQR. Q1 was answered on a 0–100 scale from excellent to terrible and Q3 was answered on a 0–100 satisfaction scale.

Table 3
Estimate and intervals for the linear mixed effect model for Q.1.

FIXED EFFECT	TYPE	COEFFICIENT	VALID RANGE
INTERCEPT ***		86.70766	
Window Distance	Continuous	−0.02354	1, 2.25 or 3.7 m [0; 11.5]
BS_No **		−2.85735	[0; 9.4]
BS_Avg_L		2.01265	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

negative linear relationship (i.e. inverse relation) with the subjective responses to Q1. Table 4 shows this information related to Model (3).

3.2. Hypothesis 2

Hypothesis 2 explicitly explored the effect of SST on view assessment and satisfaction of view. The photometric compositions of different view

Table 4
Estimate and intervals for the linear mixed effect model for Q.3.

FIXED EFFECT	TYPE	COEFFICIENT	VALID RANGE
INTERCEPT ***	Continuous	87.528	[0; 4.9]
GI		−2.135	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

conditions through solar shadings, as shown in Table 1, “Window Distance”, and SST were tested against the subjective responses. Fig. 10 shows that the BH slats are the type of solar shading that the participants rated most positively – especially in terms of satisfaction if they were to consider the usage of the solar shading for a longer period as asked by Q3. The SV slats had the lowest mean responses in both Q1 and Q3. Looking at the two graphs, it can be seen that the mean value comparison shows the same order of preference and satisfaction for these shading types. However, the distribution of the responses is varied which is captured by the LMM analysis.

$$Q.1 \sim SST_F + LC_F + \text{Participant}_R \quad (3)$$

$$Q.3 \sim SST_F + LC_F + BS\_E_F + Participant_R \quad (4)$$

The models derived are shown in Model (3) & (4). As shown in Table 5 the SSTs, a categorical variable, and local achromatic contrast (LC) were significantly associated with the subjective assessment of view out through the shadings. From the first model (3) analysis, we could see that the intercept varied with SSTs indicating that there is a significant effect on view assessments among the different SSTs. The results also confirm that the BH slats, with the largest coefficient, were the most preferred type of solar shading. The order of preference can be seen more clearly with BH being followed by BV, EX_grey, SH, EX_black, and finally the SV slats in terms of “view assessment”. The Local achromatic contrast (LC) was positively correlated to the subjective responses of Q.1: Assessment of view out. Table 6 shows the analysis results of Model (4) in association with *Q3: Satisfaction with the view*. Similarly, the different types of shading devices affect the responses significantly. Here the results show that the view from all horizontal slats was more satisfactory with BH being the most chosen the highest for a longer period of work followed by EX_B, EX_G, and SH. The vertical slats follow with SH being the least dissatisfactory of the two types. Local achromatic contrast was negatively correlated to the subjective satisfaction responses. However, the effect size was smaller for Q3 than for Q1. BS_E, being the illuminance of the bright spots detected in the scene, was also selected in the forward selection process but not statistically significant. Fig. 11 shows the local contrast variations across all view conditions with shading at 0°, slat angle. All view conditions without shading and combined are also shown in this graph. We can see that the external black shading device has the lowest local contrast calculated. The variation across other shadings is lower. EX_B shows the lowest LC. The variation across the rest of the view conditions with shading is lower, where the averaged values ranging from highest to lowest will result in the following order, BV, SV, BH, EX_grey, and SH.

Table 5
Estimates and intervals for the linear mixed effect model for Q.1.

FIXED EFFECT	TYPE	COEFFICIENT	VALID RANGE
INTERCEPT ***			
Big Horizontal slats	Categorical	107,045	
Big Vertical slats		99.669	
EX_G (Venetian blinds Grey)		98.352	
Small Horizontal slats		98.98	
EX_B (Venetian blinds Black)		92.258	
Small Vertical slats		84.606	
LC (Local achromatic Contrast) ***	Continuous	20.903	[0.85; 2.22]

***p < 0.001,**p < 0.01, *p < 0.05.

Table 6
Estimates and intervals for the effect model for Q.3.

FIXED EFFECT	TYPE	COEFFICIENT	VALID RANGE
INTERCEPT***			
Big Horizontal slat	Categorical	92.3352	
EX_B (Venetian blinds Black)		82.8835	
EX_G (Venetian blinds Grey)		81.6692	
Small Horizontal slats		81.813	
Big Vertical slats		80.7602	
Small Vertical slats		66.0428	
LC (Local achromatic Contrast) ***	Continuous	−11.628	[0.85; 2.22]
BS_E	Continuous	1.27	[0; 5.21]

***p < 0.001, **p < 0.01, *p < 0.05.

3.3. Hypothesis 3

Hypothesis 3 explored the “Interruption of view”, “Shading Angle”, and “Window Distance”, and the resulting photometric composition effects on the participants’ view assessment and satisfaction with the view. Fig. 12 illustrates the distribution of all subjective responses and the related frequencies for vertical and horizontal slat directions (the figures only include data with slat angles of 0°, i.e., with slats perpendicular to the windowpane). The view conditions with vertical slats were generally assessed lower than with horizontal slats. The slats creating the solar shadings, regardless of the direction, created interruptions of the view out. If the distance between the slats was small, they caused many interruptions in the field of view for a person looking out the window. Conversely, when the distance was big it caused few

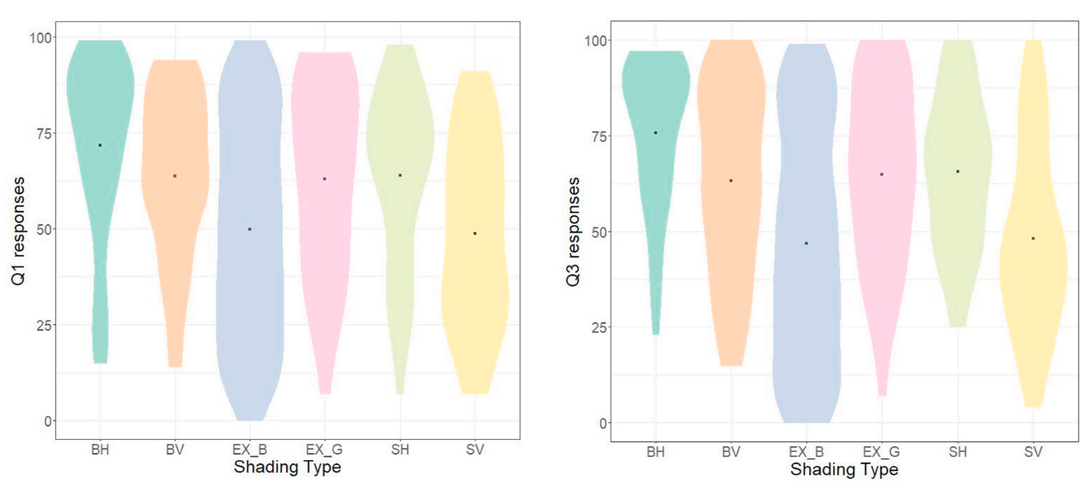

Fig. 10. The distribution and frequency of all responses for questions Q1 and Q3 for all view conditions with shading for each of the SSTs. The mean participant response is marked with a grey dot for each condition.

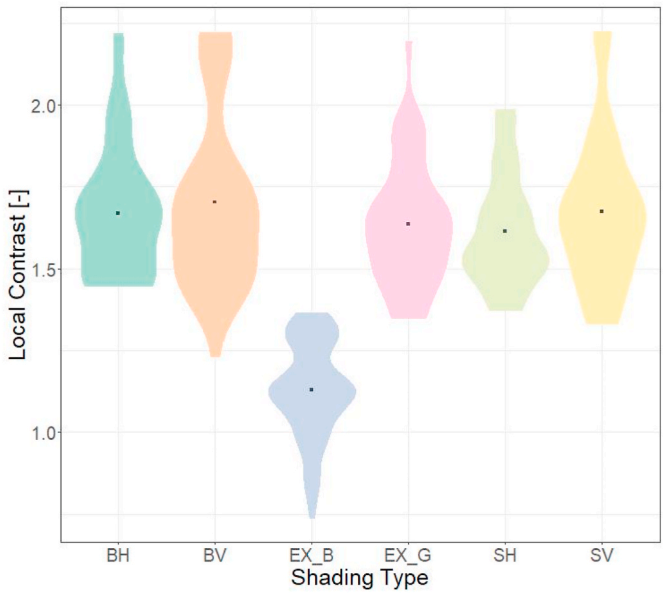

Fig. 11. Local contrast variations across all view conditions with shading.

interruptions. Hence, the SSTs were categorized into two levels, few and many interruptions. The two types of Venetian blinds together with the small horizontal and small vertical types caused many interruptions and the big horizontal and big vertical types caused few interruptions in the field of view for the participants. Fig. 13 shows the distribution and frequency of the responses for Q1 and Q3, when the participants assessed view conditions including shading types causing respectively few or many interruptions in the field of view. The subjective responses were higher when the slats caused few interruptions than with many interruptions, independent from the view position. Both the subjective assessment and the satisfaction of the view decreased with increasing slat angle and were in general lower than with no shading (see Fig. 14).

The general linear mixed effect model for hypothesis 3 had the following form:

$Q.1 \sim \mathit{ShadingDirection}_F + \mathit{Interruption}_F + \mathit{Shading\ Angle}_F + \mathit{LC}_F + \mathit{Participant}_R$

$Q.3 \sim \mathrm{ShadingDirection}_F + \mathrm{Interruption}_F + \mathrm{Shading\ Angle}_F + \mathrm{GC}_F + \mathrm{Participant}_R$

The subjective assessment was significantly correlated with the slat direction, the number of interruptions, the slat angle, and the Local achromatic Contrast as shown in Table 7. Horizontal slats were associated with a higher assessment than vertical slats. Few interruptions were associated with higher assessment than many interruptions and the effect size of interruptions and slat direction was similar resulting in similar intercepts between horizontal slats with many interruptions and vertical slats with few interruptions. As can be seen in Tables 7 and 8 LC and GC had significant effects on view assessment and view satisfaction, respectively. LC was negatively correlated with view assessment whereas GC had a positive correlation with view satisfaction through the shadings.

4. Discussion

Characterization of the view and view through the solar shadings was tested based on a photometric composition as shown in Table 1. In addition to this table, we have assessed variables such as “Window Distance” in all hypotheses, SST in hypothesis 2, and “Shading Angles”, and “interruptions to view” in hypothesis 3. We investigated several variables related to shading, specifically focusing on slat dimensions and angles. Other parameters, such as reflectivity influenced by texture and colour, could impact the visual field. However, these variables were not included in this study. In this study, we focused on results based on responses to Q1 and Q3 of the questionnaire. We used a continuous scale for the response variable to facilitate analysis with linear mixed-effects models. Continuous response variables are suitable for mixed-effects models, whereas categorical response variables with repeated measures necessitate the use of generalized linear mixed-effects models, machine learning [52], or personalized models for each participant [53]. Using linear mixed effects models we assumed a linear scale. We did not investigate if all participants perceived the scale as linear. The continuous scale was implemented in the survey using a slider with a starting position to the left, on ’Excellent’ and ’Very Satisfying’. This could have introduced an anchoring bias in the votes towards the left side of the scale. The objective of this study was to investigate the impact of shading design on the subjective response. As such, we were more interested in the difference between votes than the absolute value of the votes on the scales.

Our first hypothesis was that the photometric composition of different view conditions affects the subjective assessments.

The result showed that window distances and the number of bright spots (BS_No) in the field of view helped explain the participants’ view quality assessments, i.e., responses to Q1. The association was negative

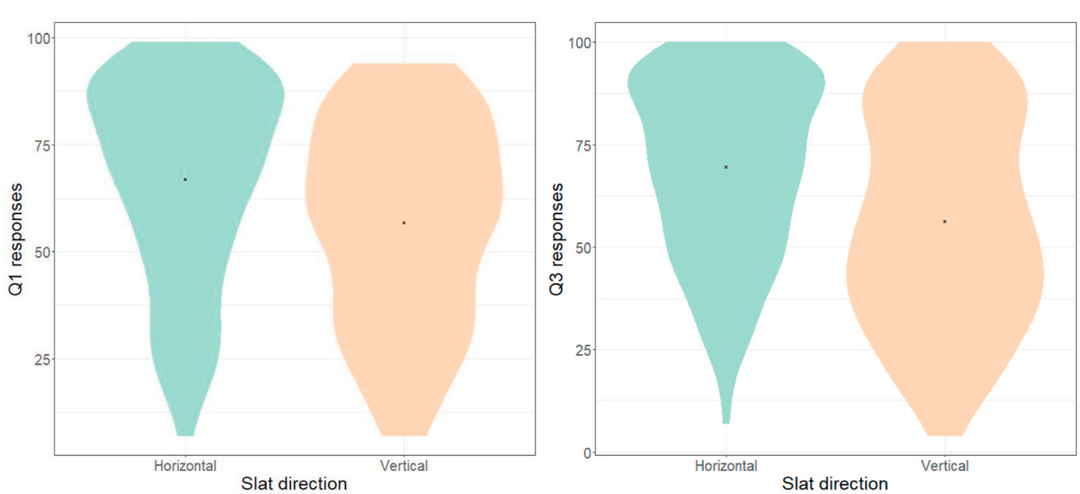

Fig. 12. The distribution and frequency of responses to Q1 and Q3 for view conditions including solar shading with 0° slats in horizontal and vertical directions. The mean participant response is marked with a grey dot for each condition.

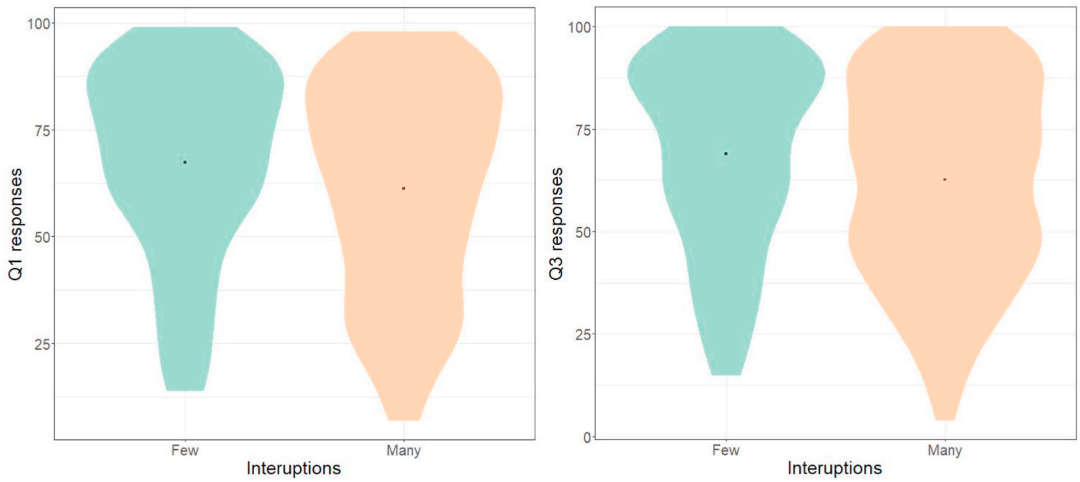

Fig. 13. The distribution and frequency of responses to Q1 and Q3 for view conditions including solar shading with 0o slats causing few and many interruptions. The mean participant response is marked with a grey dot for each condition.

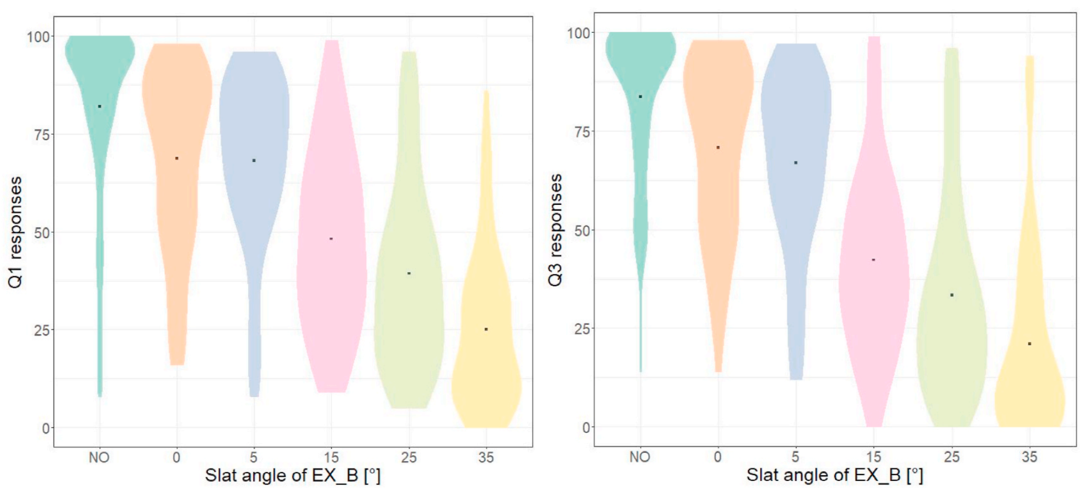

Fig. 14. The distribution and frequency of responses to Q1 and Q3 all view outs and view positions for the different slat angles. The view condition without shading is added as a reference for the impact of the solar shading. The mean participant response is marked with a grey dot for each condition.

Table 7
Estimates and intervals for the linear mixed effect model for Q.1.

FIXED EFFECT					
INTERCEPT					
	DIRECTION* **	**INTERUPTION*** **	**ANGLE*** **	**COEFFICIENT**	**RANGE**
	horizontal	*few*	0	97.9597	
	horizontal	*few*	5	97.1742	
	horizontal	*few*	10	76.8292	
	horizontal	*few*	25	67.8418	
	horizontal	*few*	35	53.5916	
	horizontal	*many*	0	86.4349	
	horizontal	*many*	5	85.6494	
	horizontal	*many*	10	65.3044	
	horizontal	*many*	25	56.317	
	horizontal	*many*	35	42.0668	
	Vertical	*few*	0	86.9037	
	Vertical	*many*	0	75.3789	
LC**				−15.0581	[0.74; 2.22]

***p < 0.001, **p < 0.01, *p < 0.05.

so an increase in BS_No was associated with a decrease in the view quality assessment. The calculated glare impact (GI) affected the participants' satisfaction, i.e. responses to Q3. However, the association was not statistically significant.

The participants' distance to the window, while explanatory in terms of view assessment, was not significant. A variety of window distances were present by choosing the five view positions in each setup relative to the respective view directions. The resulting view conditions from each

Table 8
Estimates and intervals for the linear mixed effect model for Q.3.

FIXED EFFECT					
INTERCEPT					
	DIRECTION* **	**INTERRUPTION*** **	**ANGLE*** **	**COEFFICIENT**	**VALID RANGE**
	horizontal	*few*	0	74.3994	
	horizontal	*few*	5	71.8738	
	horizontal	*few*	10	47.2692	
	horizontal	*few*	25	38.3147	
	horizontal	*few*	35	26.6721	
	horizontal	*many*	0	62.1618	
	horizontal	*many*	5	59.6362	
	horizontal	*many*	10	35.0316	
	horizontal	*many*	25	26.0771	
	horizontal	*many*	35	14.4345	
	Vertical	*few*	0	59.4742	
	Vertical	*many*	0	47.2366	
GC**				1.1675	[0; 0.74]

***p < 0.001, **p < 0.01, *p < 0.05.

viewpoint, however, encompassed varying degrees of ground, landscape, and sky, or a combination of at least two of these elements. , across different window distances. Hence, the window distance considered, i.e. 1 m, 2,25 m, and 3.7 m, did not result in a wider range of view conditions in this case. This can explain how the window distance while resulting in varying subjective responses, did not show a significant effect.

Except for a few outliers above 15k cd/m^2 (as a result of reflections or direct sunlight), the identified areas in FOV as "Bright Spots" ranged between a minimum of 75 cd/m^2 and a maximum of 500 cd/m^2. Despite these spots not being detected as glare sources and the light levels in the scene being at moderate adaptation levels ($\overline{La}$ 35 cd/m^2, min La 0.7, and max La at 283 cd/m^2, $\overline{Vert\_E}$ 98 lux), the results show that the presence of several brighter spots in FOV can create negative effects on view perception. This is aligned with the definition of the glare phenomenon as conditions with "unbalanced luminance levels" [54] in FOV. The negative association between BS_No and view assessment even at low adaptation levels underlines the importance of balanced luminance levels in the field of view, not only in terms of glare assessment but also in terms of view quality. In summary

The Significant Finding.

- Only BS_No had a significant negative correlation (i.e. inverse relation) with subjective responses to Q1.

Conclusion:

- Window distance helped explain variance in subjective responses.
- Specific photometric elements influenced subjective responses.

The second hypothesis was set to investigate the effect of different types of solar shading systems on view assessment and satisfaction. The photometric composition was measured and investigated through six SSTs. Both the SSTs and the local achromatic contrast (LC), were significantly associated with the assessment of view out, i.e. Q1, and satisfaction with the view, i.e. Q3. The importance of the selection of specific shading types and their impact on occupants' perceptions and satisfaction in of view is hence emphasized. Local Contrast (LC) had a positive correlation with view assessments and a negative correlation with satisfaction responses. This means that while a higher local contrast was preferred when assessing the view, it had a negative effect on satisfaction with the shading device. The local contrast was calculated for the entire captured fisheye image. Therefore, for the participants with a greater distance from the window, the part of the field of view which is the window becomes remarkably smaller than for those placed close to the window. Consequently, the solar shading types' effect on the calculated LC was not fully captured and represented a lower variation. Another observation rising from the experimental setup was the lower levels of window luminance in rooms C & D as a result of smaller access to the sky and lower view quality. This can be observed in Fig. 11 where EX_B represents the lowest contrast levels. Despite the two observations in terms of the calculated LC, it is still difficult to explain why LC affects the view assessment and satisfaction with varying trends between the two responses.

In summary:

Significant Findings.

- BH slats were the most preferred solar shading type for both Q1 and Q3.
- LC (Local Contrast) significantly affected view assessment and satisfaction but in opposite directions.
- Shading types significantly affected subjective assessments and satisfaction.

Conclusion:

- Solar shading types influenced both view assessment and satisfaction.

The third and final hypothesis addressed the effect of the solar shading characteristics (i.e. interruption of the view, defined based on the slat direction, the number of slats, and the slat angle) on the perception of view. The horizontal slats and configurations causing fewer interruptions were associated with higher subjective assessments and satisfaction. The decrease in subjective responses with increasing slat angle suggests a negative impact on perceived view quality. The correlation between slat direction, interruptions, and subjective responses highlights the importance of these factors in shaping occupants' perceptions of view through shading devices. Additionally, the significant effects of LC and GC on view assessment and satisfaction underscore the role of contrast in influencing the visual experience through solar shading. LC had a strong negative effect on view assessment. The global contrast GC had a significant positive effect on view satisfaction but with a smaller effect size, compared to LC. There is an intrinsic difference between the two calculations. When the shading system is added to the window, the LC is highly dependent on the pixel-by-pixel luminance levels in the image. However, global contrast is calculated based on the average luminance levels of the brighter areas to the darker areas in the scene. Hence, the global contrast, the values naturally decrease when adding denser solar shading to the view out. In the case of global contrast, it can be seen that the addition of the shading device and the resulting lower contrast is aligned with the dissatisfaction with the view.

In summary:

Significant Findings.

- Horizontal slats were associated with higher subjective responses than vertical slats. This was true for both view assessment and the satisfaction with view.
- Conditions with few interruptions had better subjective responses than conditions with many interruptions. This was true for both view assessment and the satisfaction with view.
- LC (Local achromatic contrast) had a negative correlation (i.e. inverse relation) with view assessment.
- GC (General contrast average) was positively correlated with view satisfaction.
- Conclusion:
- Slat direction, interruption frequency, and photometric elements significantly impacted view assessment and satisfaction.

Finally, the quality of the view was assessed initially using the D&V analysis method [4,9], yielding the View Quality Rating (VQR). Surprisingly, it was observed that the VQR had no significant impact on participants' perception of the view when assessing it. It is worth noting that the VQR was derived by asking participants to assess the view using pictures, while we asked the participants to assess the actual view through a window. The missing association between VQR and subjective assessments could suggest a weak link between view assessments using pictures and assessments of real views through a window. The missing association could also be attributed to inadequate instructions provided for the various factors outlined in the D&V analysis method's flow chart, or the limited variation in the view-outs used in the experiments. Notably, certain elements such as parked cars did not exert the anticipated negative influence on view assessments.

Several limitations inherent in the experiment could impact the representativeness of the findings. The participants were exposed to a setting resembling an office environment, specifically a cellular office/small landscape office. The results are representative of this setting and may show similar tendencies in other office environments or working settings. In the experimental setup, the electric lights were kept off at all times to avoid biases and confounding elements. However, this could affect the contrast levels between the interior and exterior. The composition and distribution of participants' impact representativeness. Despite efforts to include a diverse group, constraints resulted in reduced diversity. Most participants were university students aged 20–29, but demographic characteristics such as gender and experience were evenly distributed. Although the results represent this population and age group, a diverse sample should be considered. The sample included Danish- and English-speaking groups with different cultural backgrounds with different expectations of view and shading devices. Conducting experiments in spring or summer would have provided a wider range of data, including glary situations relevant to investigating the view out. The calculation of Local and Global Contrast for the entire fisheye image introduces spatial variations that may not fully capture the impact of solar shading types on LC, especially for individuals farther from the window. A wider range of weather and sky conditions along with regional contrast calculation for different parts of the field of view or window area can enhance the results and will be checked in future studies.

5. Conclusion

When solar shading systems were in use, the local contra was significantly associated with both assessments of view and satisfaction with the view. The association between local contrast and view assessment was positive, and the association between local contrast and view satisfaction was negative. I.e. an increase in local contrast resulted in an increase in view assessment and a decrease in satisfaction with the view. The significant associations in opposite directions emphasize the intricate balance required in optimizing contrast levels for different aspects of occupants' visual experiences.

In general, the solar shading characteristics affected the perception of the view. Both view assessment and view satisfaction were higher with horizontal slats compared to vertical slats, suggesting a preference for uninterrupted horizontal views. In general, minimum interruption to the view, horizontal slat direction, and a slat angle of 0° were the most preferred shading characteristics. The most preferred solar shading type was Big Horizontal slats with a depth of 200 mm and a slat-to-slat distance of 180 mm. In comparison, the other types of solar shading decreased both the assessment and satisfaction with the view. The least preferred shading type was Small Vertical slats with a depth of 80 mm and a slat-to-slat distance of 80 mm. Few interruptions were associated with higher assessments compared to many interruptions. This further supports the idea that minimizing interruptions enhances the perceived view quality.

The positive correlation between Global Contrast (GC) and view satisfaction indicates the importance of overall contrast in shaping occupants' satisfaction with the view. However, the local contrast had a stronger influence on subjective responses than the global contrast.

Despite the limitations, in this study, a novel aspect of view through shadings was explored based on the variations they create in the composition of light and contrast in the field of view and their combined effect on the perception of view out. The comprehensive exploration of photometric composition, solar shading types, and interruption factors reveals nuanced insights into occupants' subjective responses to views and solar shading systems. The study emphasizes the need for a careful balance in luminance levels, choice of solar shading types, and consideration of interruption factors to optimize occupants' perceptions of view quality and satisfaction. This, combined with the knowledge gained about view-out quality and solar shading types, has the potential to serve as a basis for further development across a broader range of contrast and glare under various sky conditions, to better understand the impact of views on occupant behavior and their needs concerning shading devices to enable the prediction of view-out quality through shading devices. Considering the importance of the usage of shading devices imposed by the changing climate towards longer periods of overheating, such studies will enhance the understanding of such devices and the occupants' use of them.

CRediT authorship contribution statement

Mandana Sarey Khanie: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Rune Korsholm Andersen:** Writing – review & editing, Validation, Supervision, Formal analysis.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Mandana Sarey Khanie reports financial support was provided by Bjarne Saxhof Fonden. Rune Korsholm Andersen reports financial support was provided by The Energy Technology Development and Demonstration Programme.

Data availability

Data will be made available on request.

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O. Kjeldsen. Their dedicated efforts were instrumental in carrying out the experimentation phase and establishing a valuable database within the scope of this study.

Appendix

Appendix A

Demographic part

The questions and answer options for each of the 14 questions regarding demographic information in the questionnaire. The question Q.IE regarding perception of the indoor environment is also presented, where the answer is on an acceptability sliding scale (0–100 score).

QUESTIONS		ANSWER OPTIONS
Q.D1 :	What is your age?	___________
Q.D2 :	What is your gender?	❐ Female ❐ Male ❐ Other
Q.D3 :	How much experience do you have within the building industry? *(Both work and studies included)*	❐ Under 1 year ❐ 1-2 years ❐ 2-3 years ❐ Over 3 years
Q.D4 :	Do you use contact lenses or glasses on a daily basis?	❐ Yes ❐ No
Q.D5 :	Are you nearsighted or farsighted?	❐ Nearsighted ❐ Farsighted ❐ Neither ❐ Don't know
Q.D6 :	Are you colorblind?	❐ Yes, red/green colorblind ❐ Yes, blue/yellow colorblind ❐ No ❐ Don't know
Q.D7 :	Do you have any other limitations to your sight, besides the before mentioned? *(Glaucoma, cataract or other)*	❐ Yes ❐ No
Q.D8 :	If yes, which?	___________
Q.D9 :	Do you consider yourself sensitive to bright light?	❐ Yes ❐ No ❐ Don't know
Q.D10 :	Are you right handed or left handed?	❐ Right handed ❐ Left handed ❐ Both
Q.D11 :	How do you feel physically today?	❐ Excellent ❐ Good ❐ Okay ❐ Bad ❐ Terrible
Q.D12 :	How is your mood today?	❐ Excellent ❐ Good ❐ Okay ❐ Bad ❐ Terrible
Q.D13 :	Do you feel tired today?	❐ Yes ❐ No ❐ A bit
Q.D14 :	How does your eyes feel today?	❐ Good ❐ A little irritated ❐ Very irritated
Q.IE :	How do you in general perceive the indoor environment in the room? *(regarding temperature, air quality, smell and noise)*	Clearly acceptable ________________ Clearly unacceptable

The questions and answer options for assessment of the view conditions.

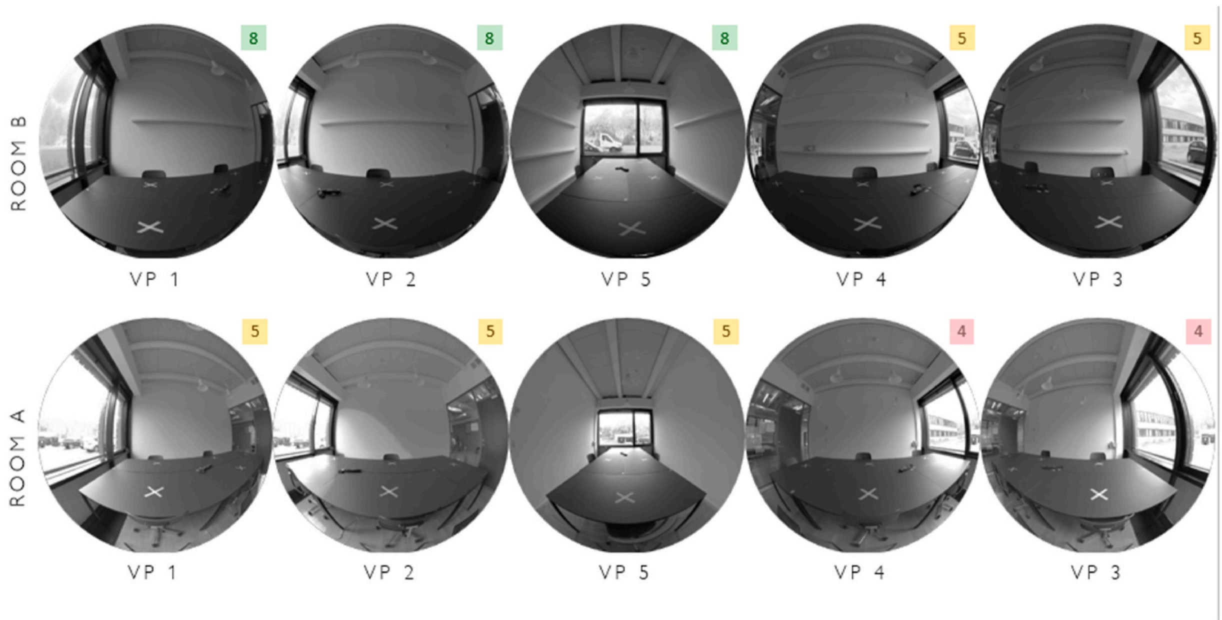
QUESTIONS		ANSWER OPTIONS
Q.1 :	How will you assess the view?	Excellent ______ Terrible
Q.2 :	How acceptable do you think the view is under the current conditions?	Clearly acceptable ______ Clearly unacceptable
Q.3 :	How would you feel about working under this view condition for a longer period?	Very satisfying ______ Very unsatisfying
Q.4 :	How would you rate this specific solar shading type?	Clearly acceptable ______ Clearly unacceptable
Q.5 :	If you could change something about the current solar shading, you would…	
Q.5.1 :	Change the slat angle?	❐ Yes ❐ No ❐ Maybe
Q.5.2 :	Increase the distance between the slats?	❐ Yes ❐ No ❐ Maybe
Q.5.3 :	Decrease the distance between the slats?	❐ Yes ❐ No ❐ Maybe
Q.5.4 :	Make the slats bigger?	❐ Yes ❐ No ❐ Maybe
Q.5.5 :	Make the slats smaller?	❐ Yes ❐ No ❐ Maybe
Q.6 :	How do you feel about the amount of view available through the current shading condition?	Very satisfying ______ Very unsatisfying
Q.7:	When you look out the window, to what extent do you feel your view is limited by the solar shading?	Not at all ______ To a great extent
Q.8:	Which of the 5 positions of the solar shading do you feel limits your view out to an unacceptable extent? (Mark all the concerned pictures)	❐ Slat angle 0 ° ❐ Slat angle 5 ° ❐ Slat angle 15 ° ❐ Slat angle 25 ° ❐ Slat angle 35 °

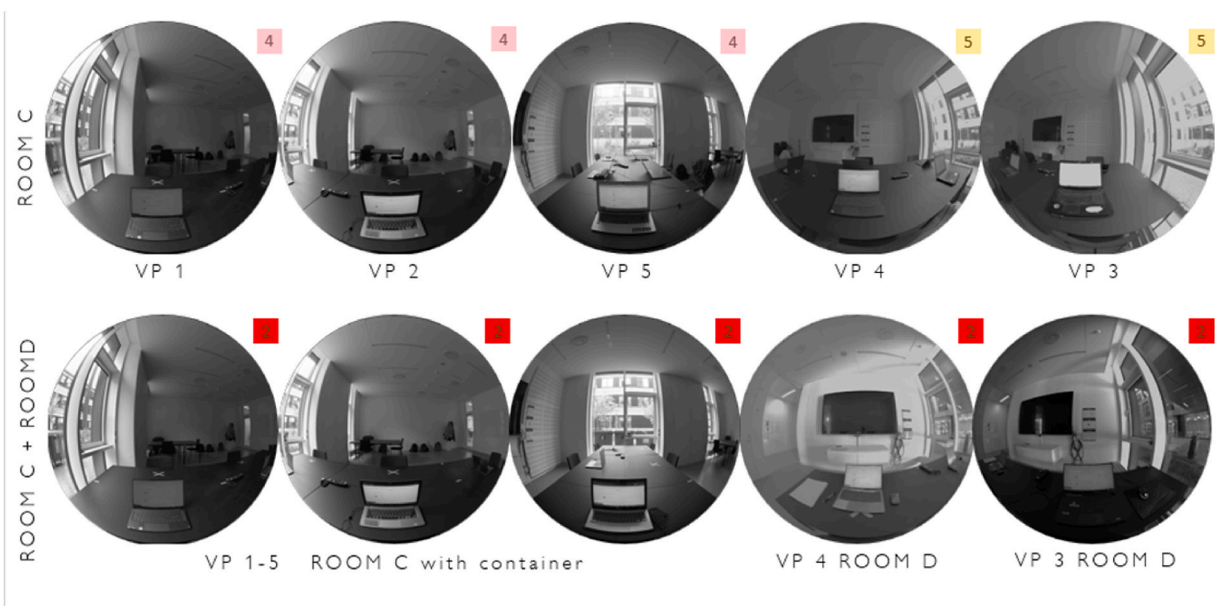
For view conditions without solar shading → Questions Q1, Q2 and Q3 are asked.

For view conditions with solar shading → Q.4 Is asked for all conditions

Appendix B

View and Visual environment from each view position.
The calculated VQRs are shown for each view.





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