Energy & Buildings 261 (2022) 111977

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enb

Lighting conditions in home office and occupant's perception: Exploring drivers of satisfaction

Natalia Giraldo Vasquez [a,b,*], Cláudia Naves David Amorim [c,*], Barbara Matusiak [d], Julia Kanno [c], Natalia Sokol [e], Justyna Martyniuk-Peczek [e], Sergio Sibilio [f], Michelangelo Scorpio [f], Yasuko Koga [g]

[a] Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark
[b] Department of Architecture and Urbanism, Federal University of Santa Catarina, Florianópolis, Brazil
[c] Faculty of Architecture and Urbanism, University of Brasilia, Brasília, Brazil
[d] Department of Architecture and Technology, Norwegian University of Science and Technology, Trondheim, Norway
[e] Department of Architecture, Gdansk University of Technology, Gdansk, Poland
[f] Department of Architecture and Industrial Design, Università Della Campania Luigi Vanvitelli, Caserta, Italy
[g] Kyushu University, Fukuoka, Japan

ARTICLE INFO

Article history:
Received 28 November 2021
Revised 7 February 2022
Accepted 18 February 2022
Available online 22 February 2022

Keywords:
Home office
Lighting
Visual environment
Perception
Satisfaction
Survey

ABSTRACT

This paper depicts lighting home office conditions within different countries and continents, emphasizing the user's satisfaction with the visual environment. The scope of this article is to investigate the drivers of participants' satisfaction with the lighting conditions at the home office. The study was developed by a team of international experts working together on Subtask A: User perspective and requirements, Task 61 IEA (International Energy Agency): Solutions for daylighting and electric lighting. An online survey was launched in December 2020 and closed on March 2021. The survey was implemented in the native languages of six participant countries (Brazil, Colombia, Denmark, Italy, Poland, and Japan) using Google Forms, and its dissemination was via various social media platforms. Measures of association between variables and predictive tests were run to explore which investigated aspects drove participants' satisfaction with the lighting conditions at the home office. We found some differences in satisfaction due to participants' sex, occupation, and participants' continent of residence. Females were more satisfied with daylight than males. Associations between the perception of seven light descriptors and satisfaction showed differences between East Asians and the rest of the participants, which might be related to the high dependence of the formers on electric lighting even when daylight is available. Design features as southern facades, the distance from the working area to the window, type of internal sun shading were related to daylighting satisfaction. Moreover, satisfaction with the general light level and the electric light was higher for those participants who did not need to switch on the ceiling, floor, or desk lamp when daylight was available. We found that an external view composed of 3 layers and the sky's visibility afforded a higher satisfaction with the window view. Having an independent room for the home office appeared to be related to a higher willingness to continue in the home office. Likewise, higher satisfaction with the overall visual environment and window view appeared to increase the willingness to continue working from home. Bridging the gap amid cultural differences and daylighting and lighting satisfaction is needed, particularly, relational studies between design features –as a response of cultural, climatic, and local practices- and occupants' preferences and acceptability. Thus, our understanding of occupants' responses will be more comprehensive. Engaging further research and measures to improve the visual environment and overall indoor environmental quality in dwellings is now a necessary step.

1. Introduction

In response to the COVID-19 pandemic, the labor market categorized workers into three groups [1]. By now, those fitted into the category "remote workers" are familiar with the home office work modality, which seems to be well accepted by some sectors [2,3].

* Corresponding authors at: Department of Civil Engineering, Technical University of Denmark, Kongens Lyngby, Denmark (N.G. Vasquez) and Faculty of Architecture and Urbanism, University of Brasilia, Brasília, Brazil (C.N.D. Amorim).
E-mail addresses: natgir@byg.dtu.dk (N.G. Vasquez), clamorim@unb.br (C.N.D. Amorim).

https://doi.org/10.1016/j.enbuild.2022.111977
0378-7788/

At the same time, education was moved to homes, overloading residential environments with different functions for which they were and still are not well prepared. Exploring the lighting conditions in home offices from the occupant's perspective is vital for understanding the quality of the perceived visual environment at home [4]. Indoor lighting can influence people's well-being, mood, and behavior, along with other functions such as circadian rhythm and alertness [5]. Overall, daylighting at home has been shown to improve people's health [6]. In dwellings, morning exposure has been associated with better sleep quality, while the perception of poor daylighting at home has been associated with occupants' self-reported depression [6] while poor artificial light in homes has been associated with safety aspects (falls and burn injuries) of the elderly [6]. However, a recent study found inconclusive results on the effects of timing and light exposure on sleep quality of Danish workers, suggesting that other parameters might be more influential than light intensity [7]. Moreover, a better understanding of user perception, needs, and satisfaction about lighting can give insights into the role of domestic lighting on the way people arrange and use the space while working from home.

The ecological perspective, which has been applied in environmental psychology, is a way of understanding people's degree of acceptance and interaction with their environment [8]. Central to this perspective is the dynamic interplay between people and their everyday environment. Stokols proposes the concept of "human-environmental optimization," that is, the processes of achieving higher degrees of fit between needs and environmental conditions. Interactions are bi-directional, meaning that the environment influences people's behavior, but when conditions are unsatisfactory, people will modify their environment. Outcomes can be disappointment, satisfaction, or enjoyment. Body senses are essential to people's experiences of the physical world [9,10]. Accepting that the mind includes aspects of the physical and social world implies that the environment's design can affect the mind and its capacity for thought, emotion, and behavior [11]. Essentially, human responses cannot be isolated from the environment [12].

The limitations imposed for controlling the virus have incentivized new research [13–18] and raised some concerns [19–22]. A comparative study identified the increased importance of windows during the lockdown [13], showing that people kept blinds and curtains open for extended periods and moved their working area closer to the window. An initial online study [14] with 60 participants identified that daylighting and artificial lighting satisfaction were positively related to the perception of high light levels, uniform distribution, and color rendering (only for satisfaction with artificial light). In their broader study with 500 participants, Aslanoğlu et al. [15] found that satisfaction with daylighting was associated with the duration of sunlight exposure, sufficiency, external view, and the window-to-floor area ratio. As for artificial lighting, satisfaction was additionally related to sufficiency and brightness perception [15]. In a follow-up study comparing working routines and employment before and after the COVID-19 lockdown in Pennsylvania, Barone Gibbs et al. [16] identified the impact of the restrictions on workers' behavior and well-being. Even though working from home increased sedentary behavior, deteriorated the sleep quality and mood, and decreased the perceived quality of life, when comparing the results from pre-shift to the shift to the home office, workers did not have a noticeable detriment of those aspects. Moretti et al. [23] found that neck and back pain caused by inappropriate workstations affects job satisfaction. In addition, participants who reported no change in job satisfaction before and after the lockdown were less productive and less stressed. For students worldwide, their mental health was deteriorated by the pandemic and the measures to control the spread of the virus, showing higher levels of anxiety, depression, and suicidal thoughts [19–22]. In addition to this, resources to make it possible to study from home are not always reachable for everybody.

The recent worldwide health crisis raised the interest of researchers and industry in the housing quality and the undeniable effects on occupants' well-being. This study, as referenced above, has its foundation in such extraordinary circumstances. This paper has been developed in the scope of the IEA/SHC Task 61 "Integrated Solutions for Daylighting and Electric Lighting" and presents further analyses of an online survey in home offices during the pandemic. Its objective is twofold: i) exploring whether satisfaction with the lighting in the home office room/area was associated with and could be predicted by personal characteristics and occupants' light perception; ii) identifying whether design features of home office impact users' satisfaction and could help to predict occupants' satisfaction and willingness to continue with the home office scheme.

2. Method

An online survey, developed in September/November 2020, was launched in December 2020 and closed on March 2021 (winter or summer season depending on the hemisphere). Six countries in three continents took part in the study: Brazil, Colombia, Denmark, Italy, Poland, and Japan. The survey was implemented in the native languages of each country using Google Forms. The English version of the survey was distributed as well across Europe. The dissemination was done among professionals and students using various social media platforms –Mailing lists, Linkedin, ResearchGate, Facebook, and Instagram.

All procedures were performed in compliance with the Declaration of Helsinki and institutional guidelines. Each participant was required to provide informed consent before starting the survey. Personal information from the participants has been anonymized. The survey was divided into six sections and contained 37 questions answered by professionals and 34 by students. In Section I- "General Information"- participants provided personal information. This Section also had a question about the location of the home office space in the house/apartment. Section II- "Lighting Condition in the whole Home Office room now"- asked about daylighting and electric lighting satisfaction at the time of the survey. Section III- "Lighting condition in the home office area now"- contained questions for assessing the perception of lighting levels and distribution, presence of glare, shadows and reflections, color rendering, and color appearance. Each question was followed by examples (pictures) to ensure a correct comprehension of the concepts. Section IV-"Pictures of Home Office" requested the participants to take two pictures with the cell phone at the survey time. Picture 1 was a photo taken from the typical sitting working position toward the window. Picture 2 was a photo of the home office area, taken 1 m away from the desk/table. Section V, "Job/ Education Information," includes additional information as time working/studying in the institution. Section VI- "Describing your Home Office"- contained 13 multiple-choice questions about the home office routine and the room features - as lighting fixtures and window shading devices. This Section also included a question about the overall satisfaction with the visual environment and the willingness to continue the home office scheme after the pandemic restrictions. Finally, through an open-ended question, participants could give their insights to improve the visual environment in case they must continue working/studying from home. The complete questionnaire and instructions for answering it can be found in [24].

2.1. Data analysis

An overview of the data collected is presented in the first part of the results. The data analysis examined whether personal

Table 1
Multiple response questions and answer options converted to binary variables.

Question	Answer option (Dummy variable)		Binary answer
28. Select the option(s) that better describe your preference(s) regarding the light in your home office:	1	I appreciate natural light as the illumination in the room	Yes / No
	2	It does not matter how the room is illuminated	Yes / No
	3	I prefer daylight for reading/writing	Yes / No
	4	I prefer electric light for reading/writing	Yes / No
	5	I prefer both daylight and electric light for reading/writing	Yes / No
	6	Other	Yes / No
30. Sun shading:	1	The window has no sun shading	Yes / No
	2	Thin curtains - it is possible to see the outdoors through the curtains	Yes / No
	3	Thick curtains - not possible to see the outdoors	Yes / No
	4	Thick curtains on the sides and thin at the middle	Yes / No
	5	Internal blinds	Yes / No
	6	External sun shading devices	Yes / No
	7	Other	Yes / No
32. Select the option(s) that better describe the electric light in your home office:	1	There is a ceiling lamp in the room with home office	Yes / No
	2	There are lamp(s) mounted on walls	Yes / No
	3	There is a floor lamp	Yes / No
	4	There is a table/desk lamp on my table	Yes / No
	5	There is specific lighting for video recording	Yes / No
	6	Other	Yes / No
33. To have good lighting at your home office workplace in the PRESENCE of daylight, you need:	1	The ceiling lamp has to be switched-on	Yes / No
	2	Wall lamps have to be switched-on	Yes / No
	3	The floor lamp has to be switched-on	Yes / No
	4	The table/desk lamp has to be switched-on	Yes / No
	5	The specific lighting for video recording has to be switched-on	Yes / No
	6	There is no need for any lamp	Yes / No
	7	Other, explain below	Yes / No
34. To have good lighting at your home office workplace in the ABSENCE of daylight, you need:	1	The ceiling lamp has to be switched-on	Yes / No
	2	Wall lamps have to be switched-on	Yes / No
	3	The floor lamp has to be switched-on	Yes / No
	4	The table/desk lamp has to be switched-on	Yes / No
	5	The specific lighting for video recording has to be switched-on	Yes / No
	6	Other	Yes / No

characteristics were associated with participants' satisfaction, the association between satisfaction and perception of different light descriptors, and the associations between design features and satisfaction. Finally, the willingness to continue the home office and the relationship with the overall assessment of the visual environment is presented together with the main predictors for continuing working/studying from home.

2.1.1. Estimating general satisfaction based on the four reported satisfaction assessments

Ratings from satisfaction with daylighting, electric lighting, window view, and general light level in the room were used to calculate a score of general satisfaction with the visual environment (namely satisfaction score). The satisfaction score was calculated through the weighted arithmetic mean, with the highest scores indicating the highest satisfaction.

2.1.2. Multiple response questions

Each answer option in multiple response questions (Section VI – Describing your Home Office) was considered as a variable with one of two possible answers: "Yes," when an answer option was selected; "No," when an option was not selected. Therefore, for further analysis of such questions (Table 1), participants' answers were broken down into several new binary variables (dummy variables).

2.1.3. Analysis of the window view quality

The authors evaluated the quality of the window view using photos taken towards the window (Picture 1). Under a simplified approach, it was identified the composition of the outside view (sky, cityscape/landscape, and ground) indicating only the amount of visible layers (1, 2, or 3) and whether one of those layers was the sky (sky visibility) [25]. The layer composition of the window view was interpreted in this study as the density of the surroundings. The analysis was only performed on those photos with visible outdoors (i.e., in pictures in which those features could be distinguished). Due to Japanese General Data Protection Regulation (GDPR), students from this country did not provide this information. Therefore, this analysis was performed only for South America and Europe.

2.1.4. Statistical approach

Participants' answers were organized into Excel spreadsheets. Experts from each country translated to English those questionnaires distributed in the mother tongue. Descriptive statistics are presented, such as the summary of statistics and visual data exploration. Collected data were categorical and scalar variables, non-normally distributed. Therefore, the association between variables was examined using non-parametric tests, such as point-biserial correlation, Kendall's τ correlation, Wilcoxon sum-rank, and Kruskal-Wallis tests [26]. Multiple regressions allowed identifying whether a variable could predict participants' satisfaction with daylight, electric light, window view, and general light level in the home office room. For all analyses, the statistical significance level was $\alpha < 0.05$. Cohen's benchmarks were used to interpret effect sizes as follows: from ± 0.1 to ± 0.29 represent a small effect, from ± 0.3 to ± 0.49 is a medium effect and from ± 0.5 to ± 1 is a large effect [26,27]. All statistical analyses were performed in R [28], for the graphical exploration was used Tableau Desktop software [29] and R using the package ggplot2 [30]. Violin plots were used to present data from discrete scales. Such type of graphical representation brings comprehensive information about data distribution. The following settings were used to format the geometry of the violin graphs: i) the width of each violin was set according to the number of answers on each category- thus, the width is proportional to the sample size; ii) colors were used to differentiate each continent; iii) jitter was applied to scatter the data points, and iv) median values were plotted (black dot).

3. Results and discussions

Even though participants' location did not reflect their nationality, especially for participants in Europe –where the inmigration is higher than in Brazil, Colombia and Japan-, in this paper, we use the terms East Asians (E. Asians), Europeans, and South Americans (S. Americans) regarding participants' residency (by continent). Six hundred ninety-four participants (34% professionals and 66% students) living in Brazil, Colombia, Italy, Poland, Denmark, and Japan answered the online survey. Most professionals were from S. America (68.8%) and most students from Europe (54.1%). Personal characteristics as sex and age were reported by the participants. Most participants were females (60%, 39.4% males, and 3 participants did not disclose this information) and young adults with ages ranging from 21 to 30 years (58.65%). Only 12.68% of the sample was between 18 and 20 years of age, 11.82% between 31 and 40 years of age and 16.86% above 41 years of age. Regarding the nature of the working/educational institution, 81.2% of scholars are studying in a public institution. Professionals were equally employees at private (41.5%), and public institutions (42.4%) and 16.1% were self-employed.

3.1. Descriptive overview of the data

3.1.1. Home office routine and physical space

Participants reported an increase in their working/studying routines. Most students (61.8%) were studying>5 days/week and late in the evening (51%), while most professionals (56.8%) said they were working 5 days/week, mainly in the typical working hours as before the pandemic (41.5%). However, 39% of professionals reported working late in the evening as well. The questionnaire provided five answer options to describe the main tasks performed during the working/studying day: a) reading and writing on digital media; b) reading and writing partially on paper, partially on digital media; c) participating in online meetings/classes; d) video recording; e) talking at the phone. In an additional answer, labeled as "Others," the participants could describe their activities if not represented by the five previous alternatives. For both students and professionals, the activities during the home office are digital-media-based reading and writing (~29% and 27%) and online meetings/classes (~28%). Additionally, partially paper-based reading and writing was also a frequent activity for students (28.1%), but was less frequent for professionals (12.8%). Another common activity among professionals was telephone talks (18.4%), and only 8.4% recorded videos.

Regarding physical space features, students were more likely to need to study in a room with a shared use: 65.1% were using the bedroom, living room, dining room, etc. Meanwhile, 48.3% of the professionals had a room dedicated exclusively to the home office, and 45% used a shared room. A small percentage of participants shared a table/desk with other house members in a shared room. Almost all participants had a window in the home office room (98.7%), with similar orientations in both groups of participants: East (avg. 19%), North/Northeast/Northwest (avg. 31.1%), West (avg. 19%), and South/Southeast/Southwest (avg. 30.8%). The distance between the window and the working/studying area was also similar between the two groups. Around 44% of the participants were located 1 m to 2 m from the window, and 30% were closer than 1 m. Only 7.9% were>3 m apart from the window. According to the assessment of the composition of the view made by the researchers, on average, most participants had an external view composed of at least two layers (54.2%), and only 22.5% of them could see three layers. Furthermore, most professionals (76.5%) and students (68.3%) had visible sky from the working area. Overall, different internal devices were the most common solution implemented for shading control (63.7%). Nonetheless, the number of professionals without any option of sun shading was higher than the number of students (23.1% and 10.8%, respectively). In addition, more students (19.9%) had external shading devices than professionals (13.4%). Widespread electric lighting solutions were ceiling fixtures (avg. 55.3%) and table/desks lamps (avg. 28.24%).

3.1.2. Participants perception, satisfaction, preferences, and behavior

Participants' perception of the lighting in the home office area at the moment of the survey was inquired through seven light descriptors. For those questions, 7-points semantic differential scales were used. Table 2 contains a summary of the results by participants' occupation. Professionals seemed to perceive the room slightly brighter with slightly more natural surfaces' colors than students. Table 3 summarizes the results by continent of residency. E. Asians perceived the distribution of the light slightly more uniform than S. Americans and Europeans. In European countries, participants perceived warmish light while other participants appeared to have a neutral perception of the color of the light. Overall, light appears to be somewhat uniformly distributed, the glare somewhat invisible, and shadows and reflections were perceived as somewhat soft and diffuse.

Four questions inquired about satisfaction with daylight, outside view, electric light, and general lighting level of the room at the moment of the survey by using 7-points Likert scales representing "ratings". Higher ratings indicated higher satisfaction with daylight, electric light, and the external view from the window. A summary of the results is presented in Table 4 and Table 5. In general, participants appeared to be satisfied by the lighting and window view. Professionals seemed to be more satisfied with the four aspects than students - especially participants in S. America seemed slightly more satisfied than E. Asians and Europeans. Both those groups, professionals and S. Americans, were more satisfied with the view to the outside. Furthermore, most stated being quite satisfied with the overall visual environment (avg. 73.6% of "Yes" and "Rather yes" answers). However, more professionals (44.9% for "Yes") answered to be satisfied with the visual environment at the home office than students did (29.3% for "Yes").

This study approached occupants' behavior as the standard action, especially regarding electric lighting according to daylight availability. Although most participants preferred as the primary source of room lighting the natural light, S. Americans (53.1%) and Europeans (49.1%) seemed to appreciate it more than E. Asians did (32.9%). For reading/writing, daylighting was preferred for S. Americans (51.8%), while E. Asians prefer combining light sources (natural and artificial, 41.8%) and electric light (21.8%). For reading/writing tasks, Europeans equally preferred both daylighting (40.3%) and combined lighting (42.8%). Likewise, more professionals than students chose the daylight for reading/writing (51.2%), and more students than professionals chose electric light (12.9%). Most participants (avg. 58.9%), especially from S. America, did not need to switch on any lamp to have good lighting when daylight is available. Nonetheless, most E. Asian participants need to switch on the ceiling fixture (37.7%) or the desk/table lamp (30.4%) to improve the lighting when daylight is available (only 24.6% said that daylighting was enough). With no daylight, most participants use a ceiling lamp (avg. 55.5%) or a desk/table lamp (28.9%) to have good lighting. Finally, more participants are willing to continue the home office doubtless (professionals = 39.4%; students = 36.9%) or are attracted to the idea of continuing the home office scheme (professionals = 34.7%; students = 29.3%).

Table 2
Assessment of the light perception separated by participants' occupation.

	Professional			Students		
	Mean	SD	Mdn	Mean	SD	Mdn
Q15 - Light level [(1) Dark – (7) Bright]	5.49	1.24	6	5.03	1.33	5
Q16 - Light distribution [(1) Uniform – (7) Varied]	3.48	1.77	4	3.31	1.69	3
Q17 - Glare [(1) Invisible – (7) Disturbing]	2.92	1.69	3	2.61	1.53	2
Q18 - Shadows [(1) Soft – (7) Hard]	2.69	1.57	2	2.76	1.56	2
Q19 - Reflections [(1) Diffuse – (7) Strong]	2.50	1.56	2	2.36	1.49	2
Q20 - Light color [(1) Warm – (7) Cold]	3.60	1.22	4	3.59	1.35	4
Q21 - Surfaces color [(1) Distorted – (7) Natural]	5.28	1.43	6	4.85	1.56	5

Table 3
Assessment of the light perception separated by continent of residency.

	E. Asia			Europe			S. America		
	Mean	SD	Mdn	Mean	SD	Mdn	Mean	SD	Mdn
Q15 - Light level	5.05	1.15	5	4.79	1.36	5	5.61	1.16	6
Q16 - Light distribution	2.66	1.55	2	3.61	1.61	4	3.26	1.81	3
Q17 - Glare	2.79	1.38	3	2.43	1.45	2	3.00	1.71	3
Q18 - Shadows	3.11	1.47	3	2.71	1.53	2	2.68	1.61	2
Q19 - Reflections	2.31	1.48	2	2.36	1.45	2	2.48	1.59	2
Q20 - Light color	3.85	1.15	4	3.35	1.38	3	3.79	1.21	4
Q21 - Surfaces color	5.25	1.45	6	4.85	1.53	5	5.10	1.54	6

Table 4
Assessments of satisfaction separated by participants' occupation.

	Professional			Students		
	Mean	SD	Mdn	Mean	SD	Mdn
Q11- Satisfaction with daylight [(1) Not at all – (7) Very satisfied]	5.51	1.43	6	5.01	1.57	5
Q12- Satisfaction with outside view [(1) Not at all – (7) Very]	5.00	1.86	6	4.14	1.92	4
Q13- Satisfaction with electric light [(1) Not at all – (7) Very]	5.16	1.34	6	4.87	1.54	5
Q14- Satisfaction with general light level [(1) Not at all – (7) Very]	5.44	1.24	6	5.19	1.37	5

Table 5
Assessments of satisfaction separated by continent of residency.

	E. Asia			Europe			S. America		
	Mean	SD	Mdn	Mean	SD	Mdn	Mean	SD	Mdn
Q11- Satisfaction with daylight	4.44	1.70	5	4.92	1.54	5	5.61	1.39	6
Q12- Satisfaction with outside view	3.61	1.70	4	4.18	1.87	4	4.88	1.97	5
Q13- Satisfaction with electric light	5.23	1.48	5	4.88	1.53	5	5.01	1.43	5
Q14- Satisfaction with general light level	5.49	1.46	6	5.01	1.33	5	5.50	1.27	6

However, more students than professionals rather not continue the home office (16.6%). Due to extensive data collected, a detailed description of the whole data set has been presented in [42] also part of special issue: Integrated Solutions for Daylighting and Electric Lighting.

3.2. Estimated general satisfaction with daylighting, lighting, and window view: Satisfaction score

The satisfaction score summarizes the general satisfaction - calculated based on the daylighting satisfaction, electric lighting satisfaction, window view, and light levels - was not different by sex. However, significant differences in the satisfaction score were found by occupation *($W = 64990$; $\alpha < 0.001$; $r = -0.16$)*. Overall, professionals were significantly more satisfied *(Mdn = 75%)* than students *(Mdn = 71%)*. Significant differences in the estimated satisfaction score were also identified due to the continent [$H(2) = 19.94$; $\alpha < 0.001$]. Participants in South America were significantly more satisfied with the overall lighting conditions *(Mdn = 75%)* than their peers in Europe *(Mdn = 68%)*. In Fig. 1 are highlighted participants with windowless home office rooms. Regardless of the lack of windows, some participants in S. American had high general estimated satisfaction. Although, such score range was wide among them. Students with no windows had a satisfaction score lower than the group median.

3.3. Association between personal characteristics and the satisfaction with lighting

Point-biserial correlations were performed to identify an association between personal characteristics such as sex and occupation (i.e. student or professional) and the satisfaction with the daylight, external view, electric light, and general light level in the room (7-points scalar/rating variables). Participants' sex was significantly related only to daylight satisfaction *($\alpha = 0.03$)* even though the relationship had a small effect *($\eta = 0.08$)*. Female participants

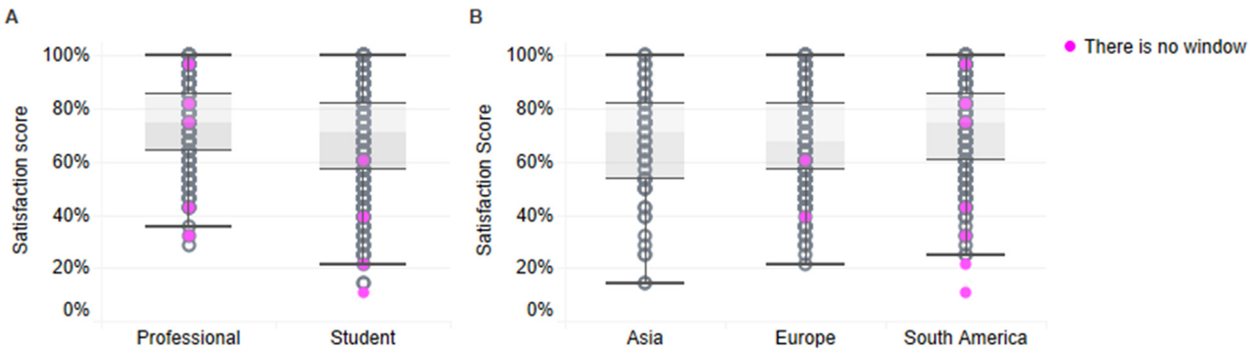

Fig. 1. Satisfaction score: Estimated general satisfaction based on four reported satisfaction assessments. (For interpretation of the references to color in the figures legend, the reader is referred to the web version of this article.)

($n = 417$; Mdn = 6) were slightly more satisfied with daylighting conditions than males *($n = 274$; Mdn = 5)*. Participants' sex was not associated with satisfaction with the external view from the window *($\alpha = 0.34$)*, electric lighting *($\alpha = 0.10$)*, and general lighting level *($\alpha = 0.31$)* in the home office room . Nevertheless, a trend indicated that females were less satisfied with the electric light than male participants *($\eta = 0.06$; $\alpha = 0.1$)*. Participants' occupation was significantly related to their satisfaction with the daylight conditions and external view *($\alpha < 0.001$)*, electric light *($\alpha = 0.01$)* and general lighting levels *($\alpha = 0.02$)*. Although, the strength of such relationships was small *($\eta = 0.09$ for electric light and general light levels; $\eta = 0.15$ for daylight; $\eta = 0.21$ for external view)*. Students were less satisfied with daylight, external view, and the general lighting level in the room than professionals (Table 4).

To consider seasonal and cultural differences, we run analyses grouping the participants by continent. By the time of the survey, South America, especially Brazil, was initiating the summer season, while Colombia is a tropical country and does not have noticeable differences in daylight availability over the year. On the other hand, in Europe (Denmark, Italy, and Poland) and E. Asia (Japan) winter season was starting. Satisfaction with daylight [$H(2) = 46.80$; $\alpha < 0.001$], external view [$H(2) = 36.37$; $\alpha < 0.001$] and with the general lighting levels was significantly affected by participants' location [$H(2) = 28.19$; $\alpha < 0.001$]. Participants in South America were significantly more satisfied with the daylight and external view than participants in Europe *($difference_{Daylight} = 90.53$; $difference_{View} = 75.21$)* and E. Asia *($difference_{Daylight} = 140.20$; $difference_{View} = 133.88$)*. Regarding satisfaction with the general light level in the room, people in South America and Japan did not significantly differ in their satisfaction (difference = 9.27). However, European participants had significantly lower satisfaction than those in South America *(difference = 77.09)* and E. Asia *(difference = 86.36)*. Critical differences were calculated for each group. The p-value for the critical difference was corrected by the number of tests *($\alpha < 0.05$)*. Participants' geographical location did not affect their satisfaction with electric light *($\alpha = 0.15$)*.

3.4. Participants' perception and their satisfaction with the visual environment

Kendall's τ tests allowed assessing the relationship between the perception of light descriptors and participants' satisfaction with daylight and electric light. Multiple regressions were run separately for the three continents data subsets to identify which light descriptors would predict better participants' satisfaction. Participants' occupation was included as well as a predictor in European and South American regressions.

3.4.1. Satisfaction with daylight

Fig. 2 presents scatterplots of daylight satisfaction and the perception of each light descriptor. Table 6 presents the correlation results. Satisfaction with daylight was significantly and strongly related to the perception of all light descriptors in E. Asian students. Such correlations showed that even under uncomfortable situations as uneven light distribution, disturbing glare, well-defined shadows, and reflections, E. Asian participants were satisfied with the daylight conditions. For Europeans, satisfaction with daylight was not associated with their perception of glare, shadows, reflections, or light color. Instead, their satisfaction was related significantly to the perception of brightness, naturalness in the color of the surfaces and certain diversity in the light distribution. Equally, in S. Americans, satisfaction with daylight was significantly and positively associated with the perception of light levels and surfaces' colors and negatively associated with light distribution, hard shadows, strong reflections, and perceptible glare. Small differences between S. Americans and Europeans assessments of perception could be due to the latitude/season of each country. In general, satisfaction with daylight was strongly and significantly related to light levels and moderately to surface color. Higher satisfaction ratings were found when the light level was perceived as brighter rather than darker with a natural appearance of surfaces' color.

Results from multiple regressions showed that, for Europeans, the light levels could reasonably predict their satisfaction with daylight *(adjusted $R^2 = 0.33$)*. Light levels and perception of surfaces' colors could predict S. Americans' satisfaction with daylight *(adjusted $R^2 = 0.33$)*. Although the correlation tests showed particular results for E. Asian students, multiple regression calculated a model in which a higher satisfaction with daylight could be strong and significantly predicted by their perception of naturalness of the surfaces' colors, perceptible glare, slightly diversity in the light distribution, and brighter room *(adjusted $R^2 = 0.94$)*. Cultural differences could be a cue for such differences, as found previously in the assessment of lighting quality, in daylit and artificially lit spaces, between South Koreans and participants from the UK [31]. Our results highlight the importance and necessity of studies with participants from other cultures.

3.4.2. Satisfaction with electric light

Fig. 3 presents scatterplots of electric light satisfaction and each and the perception of each light descriptor. Table 7 presents the correlation coefficients. For E. Asians, perception of

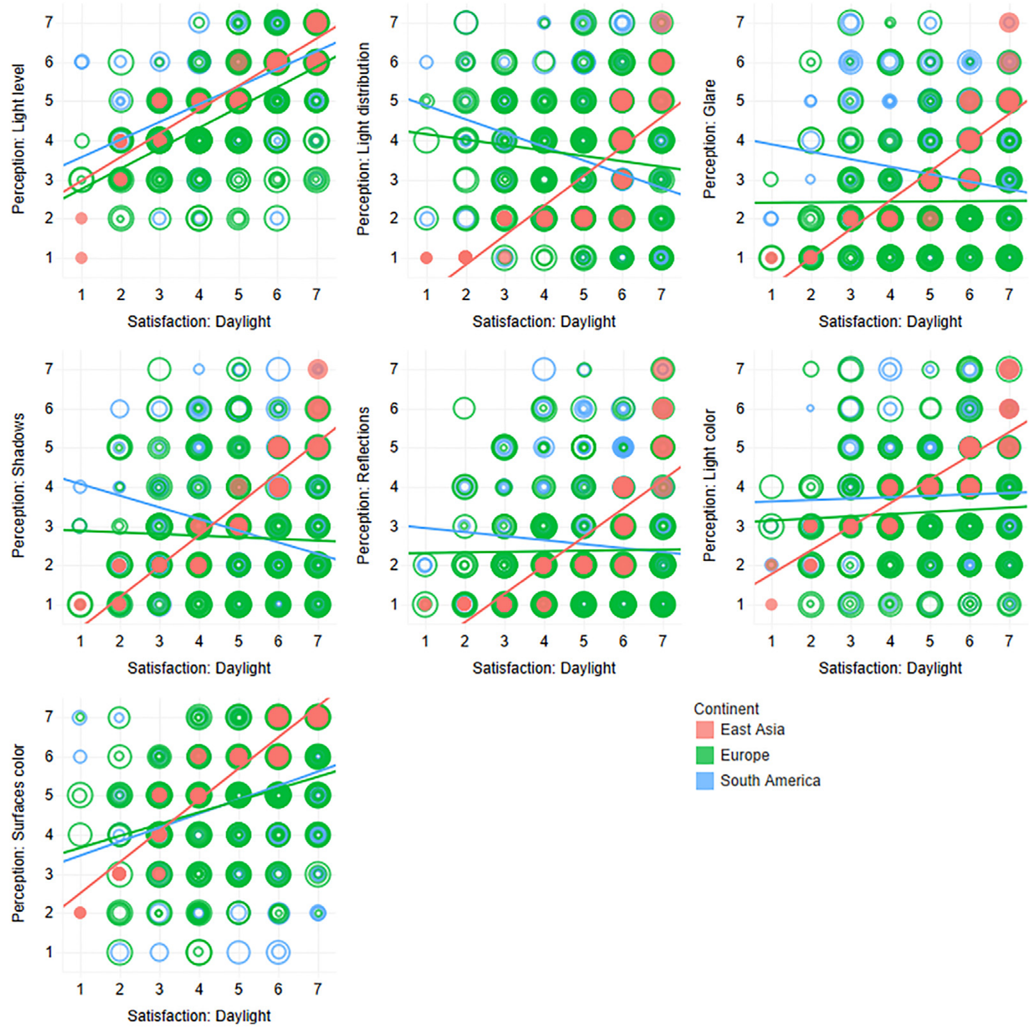

Fig. 2. Scatterplots between daylight satisfaction and the perception of each light descriptor -dot sizes are only to visualization of overlapping of some participants-.

Table 6
Kendall's τ correlation: satisfaction with daylight and perception of the light descriptors.

Satisfaction	Perception (Light descriptors)	E. Asia	Europe	S. America	All
With daylight	Q15 - Light level (Dark - Bright)	0.88****	0.50****	0.49****	0.54****
	Q16 - Light distribution (Uniform - Varied)	0.84****	-0.10*	-0.25****	-0.10***
	Q17 - Glare (Invisible - Disturbing)	0.91****	.02n.s	-0.14**	.03n.s
	Q18 - Shadows (Soft - Hard)	0.90****	-.04n.s	-0.24****	-0.07*
	Q19 - Reflections (Diffuse - Strong)	0.87****	-.01n.s	-0.11*	.02n.s
	Q20 - Light color (Warm - Cold)	0.87****	.05n.s	.01n.s	0.11***
	Q21 - Surfaces color (Distorted - Natural)	0.89****	0.25****	0.29****	0.31****

n.s = not significant (α > 0.05); * α < 0.05; ** α < 0.01; *** α < 0.001; **** α < 0.0001

all light predictors was positive and significantly associated with satisfaction with electric light. A previous study [32] showed a difference in glare assessment between European and Japanese observers about 3 to 6 points on the Unified Glare Rating scale. Participants appeared to tolerate or adapt to shadows and reflections, and, consequently, temporary strong shadows or reflections did not lead to a significant negative evaluation. Answers from the open-ended question revealed the actions taken to control glare (as changing the desk position, shutting blinds, or redirecting the lamps). For Europeans, electric lighting satisfaction was not related to the perception of shadows and reflections. Whereas perception of brightness, uniformity, glare absence, warmish light color, and naturalness in the color of the surfaces were significantly related to higher satisfaction ratings. As for S. Americans, the color of the light was the only descriptor with no association with their electric lighting satisfaction. Furthermore, in S. Americans, satisfaction with electric light was negative, small, but statistically significant associated with their perceptions of shadows and reflections.

Results from multiple regressions showed that, for E. Asians, satisfaction with electric lighting could be strong and significantly predicted by the surfaces and light color, perception of reflections, and light levels. For participants in Europe, satisfaction with electric light could be significantly predicted by the light source's color,

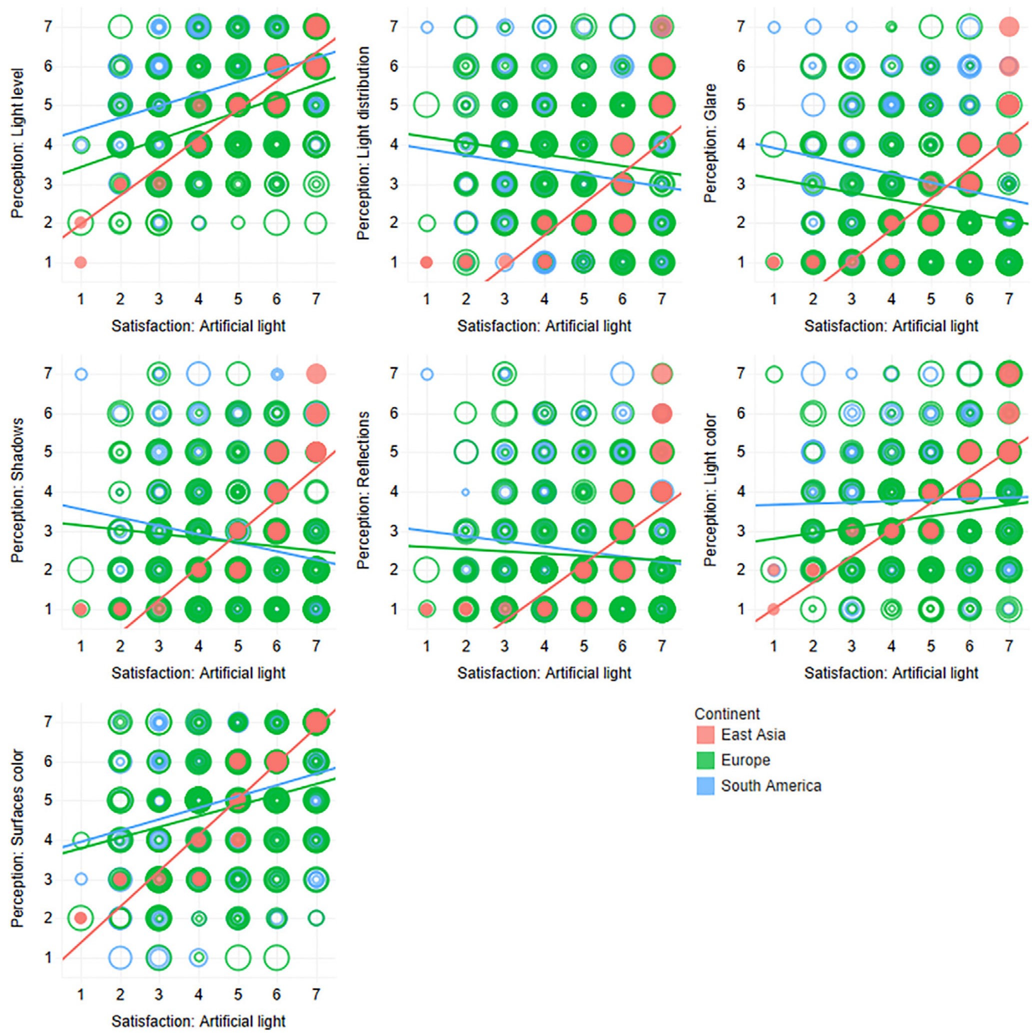

Fig. 3. Scatterplots between electric light satisfaction and the perception of each light descriptor -dot sizes are only to visualization of overlapping of some participants-.

Table 7
Kendall's τ correlation: satisfaction with electric light and perception of the light descriptors.

Satisfaction	Perception (Light descriptors)	E. Asia	Europe	S. America	All
Electric light	Q15 - Light level (Dark - Bright)	0.87****	0.32****	0.29****	0.34****
	Q16 - Light distribution (Uniform - Varied)	0.83****	-0.11*	-0.11*	-0.07*
	Q17 - Glare (Invisible - Disturbing)	0.91****	-0.15***	-0.14**	-0.07*
	Q18 - Shadows (Soft - Hard)	0.88****	-.08n.s	-0.16***	-.05n.s
	Q19 - Reflections (Diffuse - Strong)	0.82****	-.05n.s	-0.11*	-.02n.s
	Q20 - Light color (Warm - Cold)	0.86****	0.14**	.03n.s	0.15 ****
	Q21 - Surfaces color (Distorted - Natural)	0.93****	0.22****	0.20****	0.26****

n.s = not significant (α > 0.05); * α < 0.05; ** α < 0.01; *** α < 0.001; **** α < 0.0001

glare perception, and light level. For participants in South America, satisfaction with electric light could be significantly predicted by lighting levels and glare perception –participants' occupation was also a significant predictor for S. Americans.

It is worth highlighting that the survey did not include questions about lighting preferences; thus, participants' perceptions were used to examine their satisfaction. Hence, the associations did not necessarily reflect participants' preferences for the light condition at the moment of the survey. This was primarily exposed by E. Asians, who manifested being satisfied with daylight and electric light even when the perception assessment was poor. Besides inquiring about participants' perceptions, questions about participants' preferences and acceptability could bring more accurate results to understand satisfaction drivers better.

3.4.3. Satisfaction with window view

Pictures with visible external window views were used to analyze whether the external view influenced participants' satisfaction *(n = 453)*. Therefore, E. Asian participants and participants whose pictures did not identify the number of layers were not considered. Most participants had window views composed of two layers (52.8% in Europe and 55.6% in South America). More participants in Europe had window views with three layers (28.1%) than South American participants (17.3%). The sky was visible for most

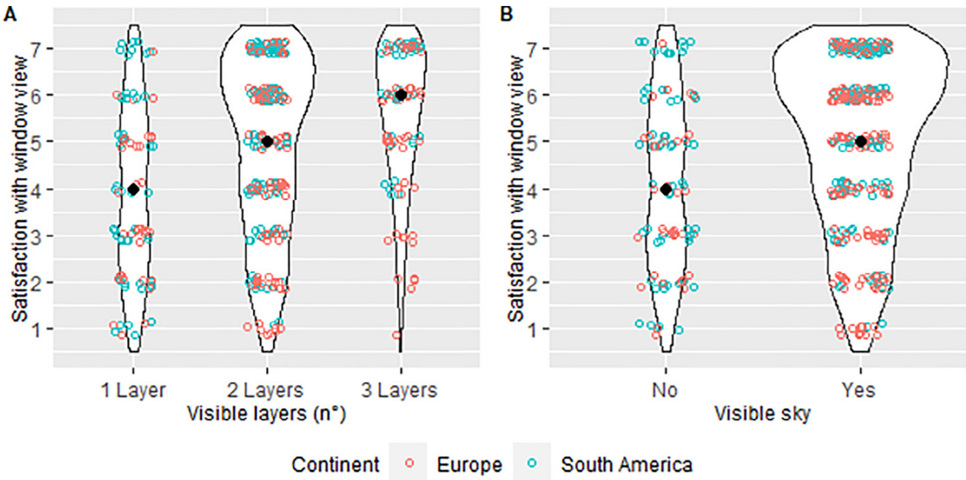

Fig. 4. Violin plots: Satisfaction with the window view due to the number of layers and sky visibility- red dot indicating Median values of each group.

participants from Europe (72.6%) and South America (69.5%). Differences in satisfaction with the external view due to the window view composition - in terms of the number of visible layers - and sky visibility were analyzed. Kruskal-Wallis test indicated significant differences in participants' satisfaction with the external view when the external view was composed of 1, 2, or 3 layers *[H (2) = 34.91; α < 0.0001]*, as presented in Fig. 4a. Participants with three layers window view had higher satisfaction ratings *(Mdn = 6; mean rank = 275.66)* than those with 2 layers *(Mdn = 5; mean rank = 233.14)* and 1 window view layer *(Mdn = 4; mean rank = 175.05)*. Multiple comparisons of the groups confirmed significant differences between all of them ($difference_{1vs.2layers} = 60.96$; $difference_{1vs.3layers} = 99.73$; $difference_{2vs.3layers} = 38.77$; $\alpha < 0.05$). Furthermore, satisfaction with the external view changed significantly when the sky was visible *(W = 10728; α < 0.0001; r = -0.18)*. Participants with visible sky were more satisfied with the external view *(Mdn = 5; mean rank = 241.56)* than participants with no visible sky *(Mdn = 4, mean rank = 186.11)* (Fig. 4b).

Multiple regressions were executed by continent using as predictors for both window view features (number of layers and sky visibility). Visibility of the sky seemed not to be a significant predictor of view satisfaction (*α > 0.05*). As for the layer composition, the results of each multiple regression indicated that the number of layers of the external view could significantly predict window view satisfaction. For Europeans, the regression model *[F(2, 196) = 8.88; adjusted* R^2 *= 0.07; α < 0.0001]* showed that the number of visible layers accounts for 7% of the variation in satisfaction. For S. Americans, the regression model *[F(2, 201) = 15.59; adjusted* R^2 *= 0.12; α < 0.0001]*indicated that layer composition accounts for 12% of the variation. View content has been proved as an important driver of well-being in buildings [33], while the benefits that natural views have on stress recovery and improvement of performance have been established [34–37]. Moreover, both children and adults seem to prefer cityscape views as long as they are far away, while natural views seem preferred when closer [38–41]. Our analyses on the window view satisfaction were limited to the sky visibility and number of layers -which could indicate the distance-. However, as previous studies found, the type of content in the window view (landscape or cityscapes) is substantial in satisfaction appraisal and this might be an explanation for the lower prediction of the number of layers on window view satisfaction. It is worth noticing that studies on window views have been performed mostly in educational and working environments, though benefits from good window views could be extended to dwellings.

Even though instructions on how to take the pictures were given to the participants, some methodological issues are worth mentioning. For instance, it would have been adequate to instruct the participants to open curtains, blinds, or shutters before taking the picture towards the window.Although restricting the time of the day to answer the survey would probably reduce our sample, this would have made it possible to make a fair comparison of the results. Thus, future studies using shared pictures from the participants are encouraged to consider this variable.

3.5. Features of home office area and satisfaction

Façade orientation, the distance between the home office area (desk or table), type of shading devices, and main components of the electric lighting system were considered as some of the design features that might influence participants satisfaction with the external view, daylighting, electric lighting and general light level. Tests of associations between the variables as well as predictive tests were performed for this purpose.

3.5.1. Window view and daylight satisfaction and the association window features

Information about the distance from the window (q31) allowed us to identify nine participants that reported windowless home office rooms. These participants were removed from these analyses. Additionally, 38 participants who chose the "The window has no sun shading" option also selected additional responses, indicating that they had sun shading control. Therefore, for those participants, the answer to the variable "The window has no sun shading" was corrected from "yes" to "no."

Satisfaction with the external view from the window did not change significantly due to the orientation (*α = 0.08*) (Fig. 5a). Although the Kruskal-Wallis test did indicate that satisfaction was significantly different when changing the distance from the window *[H(3) = 15.35; α = 0.01]* (Fig. 5b), paired comparisons showed that such difference was only significant between participants located closer to the window (<1m and 1 m-2 m) and those located 2 m to 3 m far from the window (adjusted p-value *α < 0.05*). Participants had higher satisfaction ratings with the external view when the distance from the window was shorter than 2 m *(Mdn = 5; mean rank = 351.44)*. Another design feature that might affect external view satisfaction is the type of shading device. A comparison between those participants with external shading devices and those with no external shading indicated that this

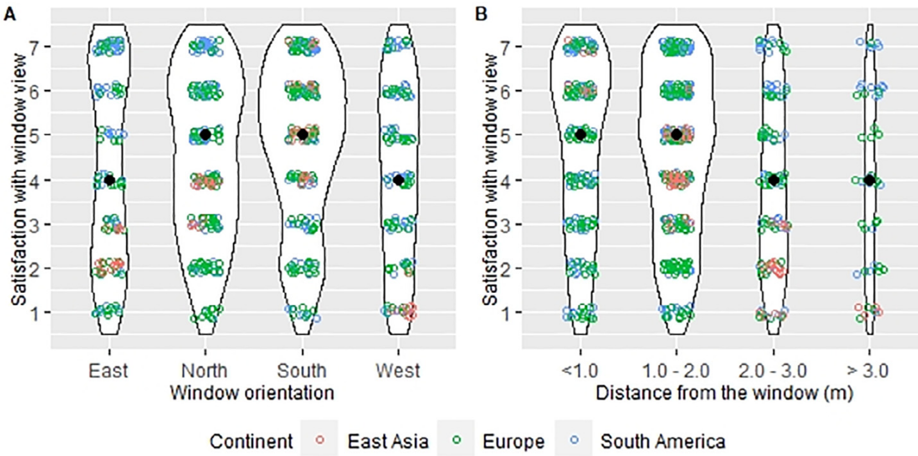

Fig. 5. Satisfaction with window view by a) orientation – South and North orientation labels covered intermediate orientations as South-east, South-west, North-east, and North-west respectively; b) Distance.

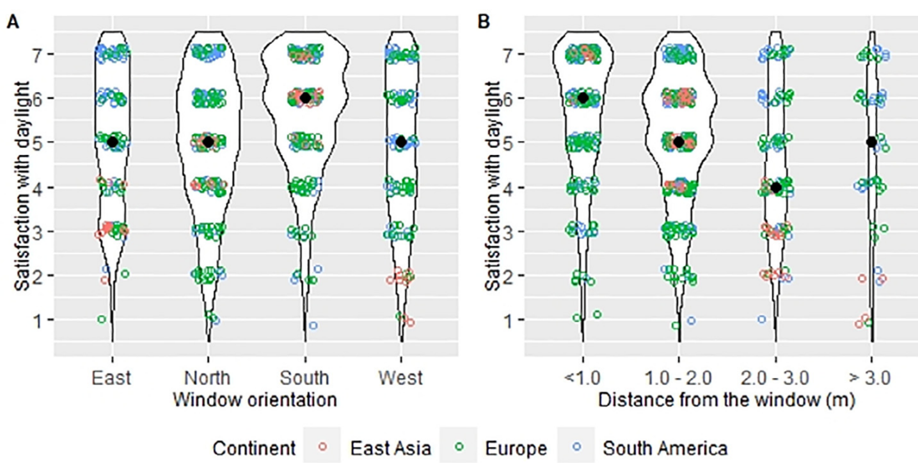

Fig. 6. Satisfaction with daylight by a) orientation – South and North orientation labels covered intermediate orientations as South-east, South-west, North-east, and North-west respectively; b) Distance.

window feature did not significantly affect their satisfaction with the external view *(α = 0.74)*.

Satisfaction with daylight changed significantly among the four orientation groups *[H(3) = 26.60 ; α < 0.0001]*. Post-hoc tests identified that participants with home office facades towards South, South-East, and South-West had higher satisfaction ratings *(Mdn = 6)* than those with facades towards East *(difference = 71.3 4)*, West *(difference = 92.06)*, and North, North-east or North-west *(difference = 80.15)* (Fig. 6a). Critical differences were calculated for each group. The p-value for the critical difference was corrected by the number of tests *(α < 0.05)*. Daylight satisfaction changed significantly due to the distance from the window *[H(3) = 39.53 ; α < 0. 0001]* (Fig. 6b). Paired comparisons (posthoc tests) showed that participants closer to the window (<1m) had higher satisfaction with daylight *(Mdn = 6)* than participants far from the window *($Mdn_{1m\text{-}2m}$ = 5; $Mdn_{2m\text{-}3m}$ = 4; $Mdn_{<3m}$ = 5)*.

Regarding the sun shading type and their relationship with daylight satisfaction, point-biserial correlations indicated that only some internal shading devices were significantly related to daylight satisfaction (Fig. 7). Participants with thick curtains covering the entire window, with no view to outside, had lower satisfaction *(η = -0.11; α = 0.002)* than those who did not have this shading option. Also, participants had higher daylight satisfaction when the shading devices were characterized as "thick curtains on the sides and thin at the middle" or "Internal blinds." Although these two sun shading types were significantly associated with daylight satisfaction, their effect was small *(η = -0.08; α = 0.04)*.

Multiple linear regression analysis examined the prediction of daylight satisfaction from participants' location (continent) and such design features – window orientation, distance from the window, and three sun-shading types. The results revealed that the two shading type's thick curtains and internal blinds were not significant predictors of daylight satisfaction *(α > 0.05)*. The model retained as statistically significant predictors of daylight satisfaction the continent, orientation (South vs. East), the distance from the window, and sun-shading characterized as thick curtains on the window sides and thin in the center. The overall regression was statistically significant *[F(11, 670) = 12.73; adjusted R^2 = 0.16; α < 0.0001]*. However, the predictors included in the model accounts for 16% of the variation in daylight satisfaction, indicating that 84% of the variation in daylight satisfaction cannot be explained by participant's location, window orientation, distance from the window and curtains features (thick in the sides and thin in the center). The model calculated for S. Americans was not significant. For Europeans, the model retained as significant predictors of daylight satisfaction facades towards south and east and

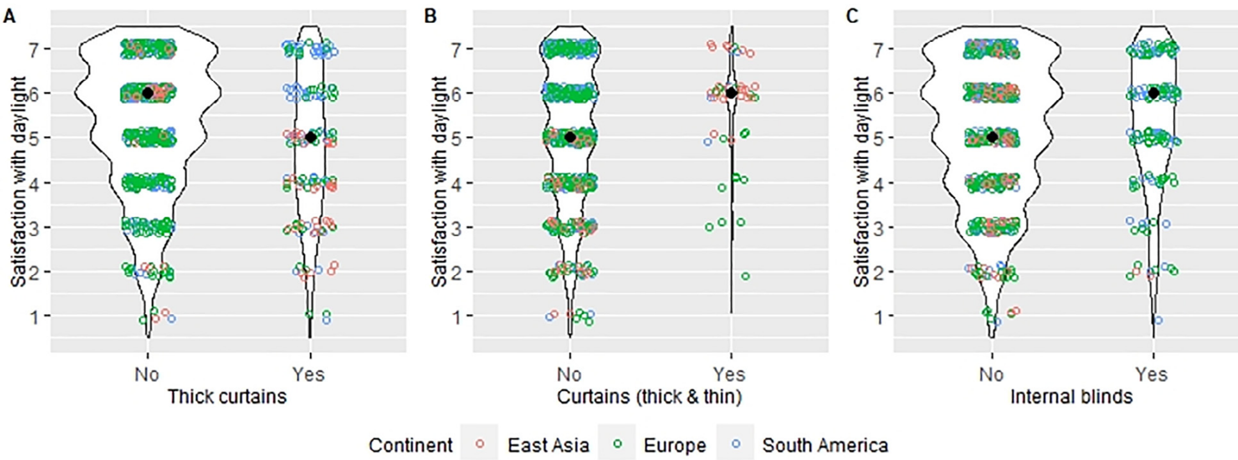

Fig. 7. Satisfaction with daylight due to the presence or not of three types of shading devices: a) Thick curtains (not possible to see the outdoors); b) Thick curtains on the sides and thin at the middle; c) Internal blinds.

distances, between the window and working area, smaller than 3 m *(α > 0.001)*. Although, the calculated model just predicted 7.2% of satisfaction variations *[F(9, 310) = 3.77; adjusted* R^2 *= 0.07; α < 0.001]*. For E. Asian, the model explained 93.5% of variations in participants' satisfaction with daylight *[F(8, 52) = 108.9; adjusted* R^2 *= 0.93; α < 0.0001]*. Internal blinds *(α > 0.05)*, facade orientation, and distance between 1 m and 2 m away from the window appeared to be highly significant predictors *(α > 0.0001)*.

3.5.2. Electric lighting features and participants satisfaction

The association between the satisfaction with the general light level and the use of electric lighting, when there is daylight availability, was examined. Significant differences in satisfaction with the general light level were identified between those participants that need to switch-on ceiling *(η = -0.27; α < 0.0001)*, floor *(η = -0.11; α = 0.002)* and desk lamps *(η = -0.11; α = 0.005)* while daylighting is available (Fig. 8a to c). Participants that need any of those lamps switched-on had lower satisfaction *[(Mdn = 5; mean rank = 246.15)*$_{ceiling\ lamps}$*; (Mdn = 4; mean rank = 156.10)*$_{floor\ lamps}$*; (Mdn = 5; mean rank = 299.53)*$_{desk\ lamp}$*]* than participants that do not need further actions on the electric lighting *[(Mdn = 6; mean rank = 375.44)*$_{ceiling\ lamps}$*; (Mdn = 6; mean rank = 350.30)*$_{floor\ lamps}$*; (Mdn = 6; mean rank = 355.86)*$_{desk\ lamp}$*]*. Furthermore, no need of any action was significantly related to satisfaction with general light level *(η = -0.30; α < 0.0001)* (Fig. 8d). Participants that stated they do not need any lamp when there is daylight availability where more satisfied *(Mdn = 6; mean rank = 390.89)* than participants that need to activate any lamp (*Mdn = 5; mean rank = 269.47)*.

The multiple linear regression revealed that satisfaction with the general light level could be predicted by: participants' continent of residency, the actions on ceiling lamps *(α = 0.04)*, and no need of using electric light while daylight is available *(α > 0.0001)*. The model *[F(6, 687) = 20.96; adjusted* R^2 *= 0.15; α < 0.0001]* accounted for 14.74% of the variation in satisfaction. Multiple linear regressions by continent presented some differences. Particularly for E. Asians, the model *[F(6, 54) = 18.98; adjusted* R^2 *= 0.64; α < 0.0001]* retained as statistically significant predictors of satisfaction the actions on desk/table lamps and no need for electric light *(α < 0.0001)*, accounting for 64.2% of the variations in satisfaction with the light level. Meanwhile, the model for Europeans *[F(6, 315) = 7.49; adjusted* R^2 *= 0.10; α < 0.0001]* only explained 10% of participants' variation in satisfaction, retaining as significant predictors to use or not specific lighting for recording video and no need of using electric light while daylight is available. For S. American participants, the model did not predict well the satisfaction with general light level *[F(4, 306) = 6.67; adjusted* R^2 *= 0.06; α < 0. 0001]* since only retained as marginal predictor the answer of no need for electric light *(α = 0.07)*. A possible explanation for such

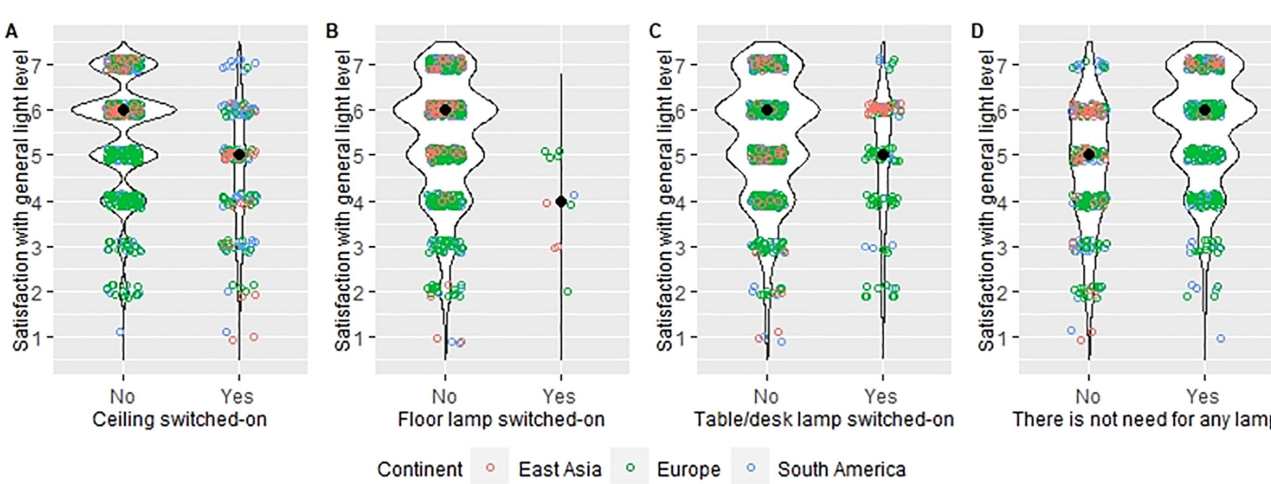

Fig. 8. Required actions to have good lighting when daylight is available. Satisfaction with general light levels and: a) The ceiling lamp has to be switched-on; b) The floor lamp has to be switched-on; c) The table/desk lamp has to be switched-on; d) There is no need for any lamp.

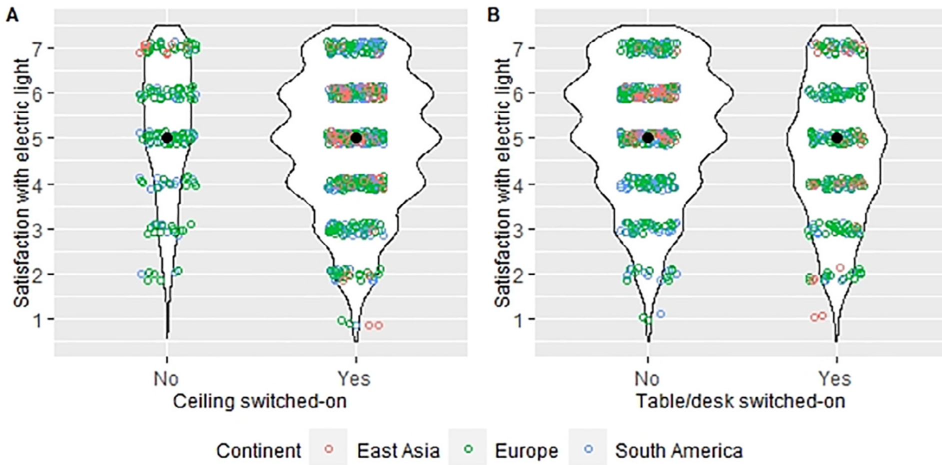

Fig. 9. Required actions to have good lighting when daylight is NOT available. Satisfaction with electric light and: a) Need of ceiling lamps and b) Need of desk lamps.

differences in the prediction by continent could be the remarked differences in the higher preference for combined lighting reported for E. Asian participants since a higher number of them need to use electric light during the daytime (see the description in 3.1.2).

Satisfaction with electric light was examined based on the perception of having good lighting when daylight is not available. When participants stated they have to switch on one or more lighting fixtures to have "good lighting," those answers are considered in this paper as the occupants' actions to achieve such perception. Point-biserial correlation tests indicated that satisfaction was significantly different between participants who needed to take action - or not- to perceive good lighting when natural light is unavailable. Although, such association was weak and statically significant only for ceiling fixtures (η = -0.11; α = 0.005) and desk lamps (η = -0.13; α = 0.0009). In both cases, the satisfaction rating was lower for those participants that need to switch-on either the ceiling lamps *(Mdn = 5; mean rank = 337.64)* and desk lamp *(Mdn = 5; mean rank = 318.43)* than for those that do not need it *[(Mdn = 5; mean rank = 380.14)*$_{ceiling\ lamps}$; *(Mdn = 5; mean rank = 366.80)*$_{desk\ lamps}$, Fig. 9*]*. These findings could point out a greater appreciation for daylight, even when unavailable.

As significant predictors of satisfaction with electric lighting, the multiple regression retained actions regarding ceiling and wall-mounted lamps. Nonetheless, the calculated model seemed to predict poorly the satisfaction with electric light when occupants need to use any of those light fixtures (R^2 = 0.04; α < 0.000 1). Differences in participants' preferences regarding the main source of light could also explain the differences found when the multiple regressions were separated by continent. The model for E. Asian participants *[F(5, 55) = 27.0; adjusted* R^2 *= 0.68;* α *< 0.000 1]* explained 68.4% of the variation in satisfaction with electric light when daylight is not available. Retained significant predictors were the ceiling, desk/table lamps, and floor lamps (α < 0.05). Models for European and S. American participants appeared to predict poorly or did not predict participants' satisfaction with electric light, respectively, even when using electric light is required.

3.6. Willingness to continue the home office after the pandemic

We examined whether participants' home office routine could predict the willingness to continue the home office, physical space features, perceptions and satisfaction with four aspects

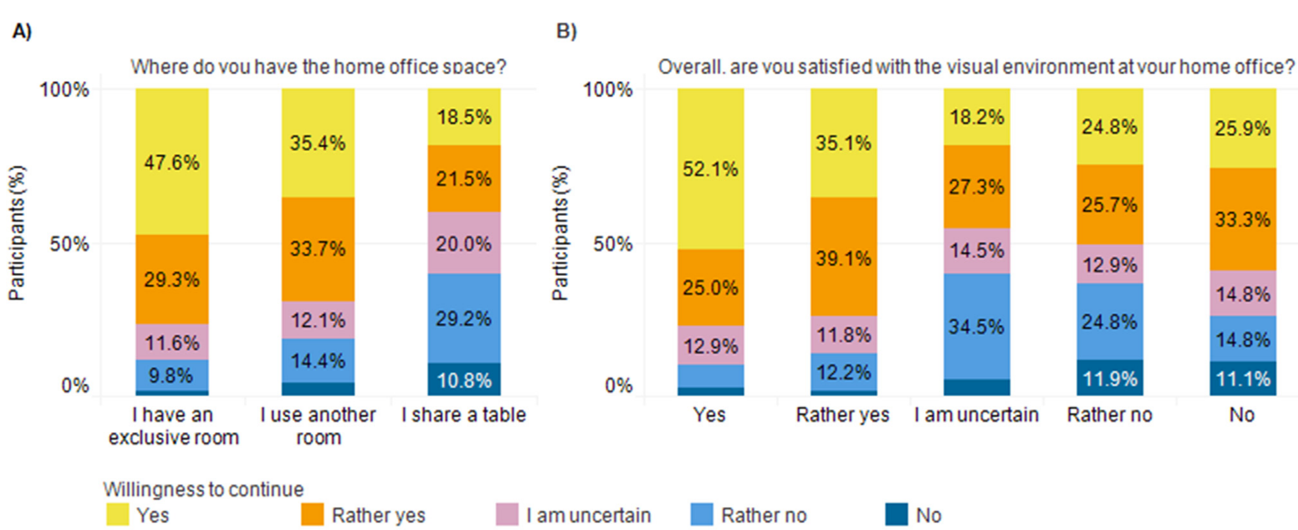

Fig. 10. Willingness to continue the home office and a) the home office room location, b) Satisfaction with the overall visual environment of the room.

(with electric lighting, daylighting, window view, and general light level), and overall satisfaction appraisal with the visual environment. Regarding home office routine, we used as predictors: days/week, working day during the pandemic, and amount of time working per day compared as before the pandemic. Regarding physical space features, the predictors were home office room location and the need to use electric light when daylight is available.

Light descriptors did not predict the willingness to remain in the home office. The four individual satisfaction assessments were neither predictors. Having an independent room for the home office appeared to be related to a higher willingness to continue in the home office. In this regard, participants with poorer conditions, as sharing the same table/desk with others, would rather not remain in the home office scheme (or were uncertain). Likewise, higher satisfaction with the overall visual environment appeared to increase the willingness to continue working from home (Fig. 10). The model retained as statistically significant predictors of the willingness: the home office location, window views with three layers, and higher satisfaction with the overall visual environment ("yes" and "rather yes"). The overall regression was statistically significant *[$F(30, 365) = 2.68$; adjusted $R^2 = 0.11$; $\alpha < 0.0001$]*. When including only the overall satisfaction with the visual environment, the location and window view layers, the model *[$F(9, 403) = 7.56$; adjusted $R^2 = 0.12$; $\alpha < 0.0001$]* retained the same predictors although, this time would be possible to conclude that such variables could predict 12% of the variation in the willingness. Since the home office could be the future for remote workers, building design aspects that could impact our performance and well-being should be further investigated. Thus, comprehensive indoor environmental quality studies are required to quantify the impact of such parameters on occupants' acceptability of the home office and their performance when working from home.

4. Conclusions

This study provides information about the associations between the home office daylighting, window view, electric lighting, and lighting levels satisfaction with participants' personal characteristics, perceptions, and design features. Based on individual satisfaction assessments, the general satisfaction with daylighting and lighting in the home office room was estimated, which appeared to be pretty adequate for most participants, even for some of those few participants with no windows.

Regarding personal variables, a marginal effect of participants' sex on satisfaction with daylight and electric light was found. Overall, students were less satisfied with the four individual aspects (daylight, electric light, window view, and lighting levels) than professionals, probably because their home office room is, in most cases, in the bedroom and living/dining room. Moreover, most of them are studying late in the evening, which might indicate an inferior design of the electric light system. Together with previous studies, our results might be helpful in the design of students' accommodations which must support not only visual comfort but also students' health and well-being. Cultural differences were noticeable between participants. East Asians appeared more tolerant to unsatisfactory lighting conditions or had lower expectations than South Americans and Europeans based on reported perception and satisfaction. Two important considerations can be pointed out from these results. First, bridging the gap amid cultural differences and daylighting and lighting satisfaction is needed, particularly, relational studies between design features –as a response of cultural, climatic, and local practices- and occupants' subjective responses. Second, questionnaires for lighting research should include questions about preferences and acceptability as well as more detail about design features (type and color temperature of lamps, room dimensions, number of windows, window glazing composition). Thus, our understanding of occupants' responses will be more comprehensive.

We found that some design features affected participants' satisfaction. Aspects as having control over shading devices, being close to the window, and having an unobstructed view to the outside were crucial for increasing participants' satisfaction. Although, in this study, design features could not predict South Americans' satisfaction with daylighting. From our data, we cannot draw an explanation for this. However, we can hypothesize that, perhaps, people from tropical regions appreciate natural light regardless of the quality of the design features due to the seasonal aspects (summer in South Brazil), daylight availability in tropical regions (Colombia and Northern Brazil), and people's lighting expectations. On the other hand, the lower satisfaction of East Asians with daylighting could be explained by the necessity of switching-on lighting fixtures while daylight is available. Unfortunately, we could not have pictures from those participants to corroborate design features and understand why they need to rely on electric lighting to have good lighting. One possible explanation could be the winter season and density of urban centers, where all participants reside, which might exacerbate the lack of daylight due to higher obstructions, blocking the external view and limiting the daylight availability. Since daylight availability and window view are affected by the building surroundings, a holistic approach of standards and local legislation is necessary to link such requirements to urban aspects and not only to the building.

We found that a high percentage of both professionals and students would certainly like to continue the home office or were attracted to it. Nevertheless, more students than professionals do not want or prefer not to continue studying from home, which could be related to each country's lockdown measures, whether they had been isolated or living with others during this period, and their mental health. As for those supporters of working from home, we identify as drivers of such willingness better conditions regarding the privacy of the home office room and overall satisfaction with the visual environment. However, we did not ask whether they would like to change their work to the home office scheme entirely or partially. Nevertheless, the post-pandemic work will be different since the home office appeared to be a well-received solution by some employees and employers. In this sense, housing projects will have some future challenges, e.g., the way to use and design residences that will embrace new activities like working and studying, increasing energy consumption from the residential sector due to allocating such activities. Additionally, it is worth noticing that studies on window views have been performed primarily in educational and working environments, though benefits from good window views could be extended to dwellings. Engaging further research and measures to improve the visual environment and overall indoor environmental quality in dwellings is now a necessary step.

Finally, we found some methodological challenges. Despite instructions for taking the pictures were provided, some participants did not follow them as we expected, or perhaps the instructions were not so clear. Therefore, testing the instructions before applying the questionnaires will help reduce missing data when instructions are needed. Studies aiming to compare temporal effects would benefit from controlling the time for collecting participants' answers, although such a strategy would reduce the sample size. An alternative way to overcome timing restrictions would be by subsetting the data during the analysis. Lastly, studies in different locations should consider subsequent data collection to cover the effects of seasonal differences and sky variability.

CRediT authorship contribution statement

Natalia Giraldo Vasquez: Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Cláudia Naves David Amorim:** Conceptualization, Methodology, Supervision, Project administration, Writing – original draft, Writing – review & editing. **Barbara Matusiak:** Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing. **Julia Kanno:** Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – review & editing. **Natalia Sokol:** Conceptualization, Data curation, Writing – review & editing. **Justyna Martyniuk-Peczek:** Conceptualization, Data curation, Writing – review & editing. **Sergio Sibilio:** Writing – review & editing. **Michelangelo Scorpio:** Data curation. **Yasuko Koga:** Data curation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We want to thank all volunteers who kindly supported this study by dedicating their time to answer our survey.

This project has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 101031380.

The study was supported by the Brazilian National Council of Scientific and Technological Development (CNPq)

This paper was a part of the collaborative work of a team of researchers and experts involved in Subtask A: *User perspective and requirements*, Task 61 IEA (International Energy Agency): *Solutions for daylighting and electric lighting.*

References

[1] World Economic Forum, The Future of Jobs Report 2020, 2020.
[2] World Economic Forum, Home-office, HQ, hybrid or work-from-anywhere? | World Economic Forum, (2021). https://www.weforum.org/agenda/2021/05/home-office-hq-hybrid-or-work-from-anywhere-this-is-what-businesses-are-planning/ (accessed 23 November 2021)
[3] A. Alexander, R. Cracknell, A. De Smet, M. Langstaff, M. Mysore, D. Ravid, What executives are saying about the future of hybrid work, 2021. (n.d.). https://www.mckinsey.com/business-functions/people-and-organizational-performance/our-insights/what-executives-are-saying-about-the-future-of-hybrid-work (accessed 23 November 2021).
[4] K.M. Gerhardsson, T. Laike, M. Johansson, Leaving lights on – A conscious choice or wasted light?, Use of indoor lighting in Swedish homes, Indoor Built Environ 30 (6) (2021) 745–762, https://doi.org/10.1177/1420326X20908644.
[5] K.M. Gerhardsson, T. Laike, M. Johansson, Residents' lamp purchasing behaviour, indoor lighting characteristics and choices in Swedish homes, Indoor and Built Environment 28 (7) (2019) 964–983.
[6] O. Osibona, B.D. Solomon, D. Fecht, Lighting in the home and health: A systematic review, Int. J. Environ. Res. Public Health. 18 (2021) 1–20, https://doi.org/10.3390/IJERPH18020609.
[7] L. Amdisen, S. Daugaard, J.M. Vestergaard, A. Vested, J.P. Bonde, H.T. Vistisen, J. Christoffersen, A.H. Garde, Å.M. Hansen, J. Markvart, V. Schlünssen, H.A. Kolstad, A longitudinal study of morning, evening, and night light intensities and nocturnal sleep quality in a working population, Https://Doi.Org/10.1080/07420528.2021.2010741. (2021) 1–11, https://doi.org/10.1080/07420528.2021.2010741.
[8] D. Stokols, Conceptual strategies of environmental psychology, in: D. Stokols, I. Altman (Eds.), Handb. Environ. Psychol., John Wiley & Sons, Ltd, new york, 1987: pp. 41–70.
[9] J. Pallasmaa, The Eyes of the Skin: Architecture and the Senses, John Wiley & Sons Ltd, Chichester, UK, 2005, http://arts.berkeley.edu/wp-content/uploads/2016/01/Pallasmaa_The-Eyes-of-the-Skin.pdf.
[10] S.E. Rasmussen, Experiencing Architecture, MIT Press, Cambridge, MA, 1964.
[11] S. Robinson, Introduction: Survival through design, in: S. Robinson, J. Pallasmaa (Eds.), Mind Archit. Neurosci. Embodiment, Futur. Des., MIT Press, Cambridge, MA, 2017: pp. 1–7.
[12] M.J. Johnson, The Embodied Meaning of Architecture, in: S. Robinson, J. Pallasmaa (Eds.), Archit. Neurosci. Embodiment, Futur. Des., The MIT Press, Cambridge, MA, 2015: pp. 33–48. https://doi.org/10.7551/MITPRESS/10318.003.0004 .
[13] A. Batool, P. Rutherford, P. McGraw, T. Ledgeway, S. Altomonte, Window Views: Difference of Perception during the COVID-19 Lockdown, LEUKOS. 17 (4) (2021) 380–390, https://doi.org/10.1080/15502724.2020.1854780.
[14] R. Aslanoğlu, P. Pracki, J.K. Kazak, B. Ulusoy, S. Yekanialibeiglou, Short-term analysis of residential lighting: A pilot study, Build. Environ. 196 (2021) 107781, https://doi.org/10.1016/j.buildenv.2021.107781.
[15] R. Aslanoğlu, J.K. Kazak, S. Yekanialibeiglou, P. Pracki, B. Ulusoy, An international survey on residential lighting: Analysis of winter-term results, Build. Environ. 206 (2021) 108294, https://doi.org/10.1016/j.buildenv.2021.108294.
[16] B. Barone Gibbs, C.E. Kline, K.A. Huber, J.L. Paley, S. Perera, Covid-19 shelter-at-home and work, lifestyle and well-being in desk workers, Occup. Med. (Chic. Ill). 71 (2021) 86–94, https://doi.org/10.1093/OCCMED/KQAB011.
[17] B.. Matusiak, C. Amorim, S. Sibilo, J. Martyniuk-Peczek, N. Sokol, Y. Koga, J. Debik, HOME OFFICE SURVEY IN THE SCOPE OF THE IEA SHC TASK 61, THE LIGHTING CONDITIONS, in: CIE 2021 Midterm Meet. Conf. Light Life - Living with Light, Malaysia, 2021.
[18] C.N.D. Amorim, N.G. Vasquez, J.R. Kanno, Lighting conditions in Brazilian and Colombian home offices: a preliminary study based on occupanńs perception, in: CIE 2021 Midterm Meet. Conf. Light Life - Living with Light, CIE, Malaysia, 2021.
[19] N. Meda, S. Pardini, I. Slongo, L. Bodini, M.A. Zordan, P. Rigobello, F. Visioli, C. Novara, Students' mental health problems before, during, and after COVID-19 lockdown in Italy, J. Psychiatr. Res. 134 (2021) 69–77, https://doi.org/10.1016/J.JPSYCHIRES.2020.12.045.
[20] X. Wang S. Hegde C. Son B. Keller A. Smith F. Sasangohar Investigating Mental Health of US College Students During the COVID-19 Pandemic: Cross-Sectional Survey Study J Med Internet Res 22 9 e22817 10.2196/22817
[21] A. Essadek, T. Rabeyron, Mental health of French students during the Covid-19 pandemic, J. Affect. Disord. 277 (2020) 392–393, https://doi.org/10.1016/J.JAD.2020.08.042.
[22] C. Son S. Hegde A. Smith X. Wang F. Sasangohar Effects of COVID-19 on College Students' Mental Health in the United States: Interview Survey Study J Med Internet Res 22 9 e21279 10.2196/21279
[23] A. Moretti F. Menna M. Aulicino M. Paoletta S. Liguori G. Iolascon Characterization of Home Working Population during COVID-19 Emergency: A Cross-Sectional Analysis IJERPH 17 17 6284 10.3390/ijerph17176284
[24] B.S. Matusiak, J. Martyniuk-Pęczek, S. Sibilio, C.N.D. Amorim, M. Scorpio, G. Ciampi, M. Nazari, N. Sokol, J. Kurek, M. Waczyńska, N.G. Vasquez, J.R. Kanno, Subtask A : User perspective and requirements A.3 Personas, 2021. https://doi.org/10.18777/ieashc-task61-2021-0009 .
[25] EN European Committee for Standardization, EN 17037:2018 Daylight in buildings, CEN, Brussels, 2018.
[26] A. Field J. Miles Z. Field Discovering Statistics Using R 1st ed., 2012 SAGE Publications Ltd London 10.7326/M16-0968
[27] C.P. Dancey, J. Reidy, Statistics Without Maths for Psychology, 8th ed.,., Pearson Education Australia, 2020.
[28] R Core Team R A language and environment for statistical computing. R Foundation for Statistical Computing 2021 https://www.r-project.org/
[29] Tableau Software, Tableau Desktop, (2021). www.tableau.com/products/desktop .
[30] H. Wickham, ggplot2: Elegant Graphics for Data Analysis, Springer-Verlag, New York, 2009, http://ggplot2.org.
[31] D.H. Kim, K.P. Mansfield, A cross-cultural study on perceived lighting quality and occupants' well-being between UK and South Korea, Energy Build. 119 (2016) 211–217, https://doi.org/10.1016/J.ENBUILD.2016.03.033.
[32] Y. Akashi, R. Muramatsu, S. Kanaya, Unified Glare Rating (UGR) and subjective appraisal of discomfort glare, Http://Dx.Doi.Org/10.1177/14771535960280040501. 28 (4) (1996) 199–206, https://doi.org/10.1177/14771535960280040501.
[33] R.S. Ulrich, View Through Window May Influence Recovery from Surgery 224 (1984) 420–422, https://doi.org/10.1126/science.6143402.
[34] R.S. Ulrich, Natural versus urban scenes: Some Psychophysiological Effects, Environ. Behav. 13 (5) (1981) 523–556, https://doi.org/10.1177/0013916581135001.
[35] R. Kaplan, The role of nature in the context of the workplace, Landsc. Urban Plan. 26 (1-4) (1993) 193–201, https://doi.org/10.1016/0169-2046(93)90016-7.
[36] J.A. Benfield, G.N. Rainbolt, P.A. Bell, G.H. Donovan, Classrooms With Nature Views: Evidence of Differing Student Perceptions and Behaviors, Environ. Behav. 47 (2) (2015) 140–157, https://doi.org/10.1177/0013916513499583.
[37] D. Li W.C.W.C. Sullivan Impact of views to school landscapes on recovery from stress and mental fatigue Landsc. Urban Plan. 148 2016 149 158 https://doi.org/https://doi.org/10.1016/j.landurbplan.2015.12.015
[38] S. Kaplan, J.S. Wendt, Preference and the visual environment: complexity and some alternatives, in: Environ. Des. Res. Pract. Proc. Environ. Des. Res. Assoc. Conf. Three, Los Angeles (Vol. 6)., 1972: pp. 1–5.

[39] S. Kaplan, R. Kaplan, J.S. Wendt, Rated preference and complexity for natural and urban visual material, Percept. Psychophys. 12 (4) (1972) 354–356, https://doi.org/10.3758/BF03207221.

[40] N.G. Vásquez, M.L. Felippe, F.O.R. Pereira, A. Kuhnen, Luminous and visual preferences of young children in their classrooms: Curtain use, artificial lighting and window views, Build. Environ. 152 (2019) 59–73, https://doi.org/10.1016/j.buildenv.2019.01.049.

[41] M. Kent, S. Schiavon, Evaluation of the effect of landscape distance seen in window views on visual satisfaction, Build. Environ. 183 (2020) 107160, https://doi.org/10.1016/j.buildenv.2020.107160.

[42] Cláudia Naves David Amorim, Natalia Giraldo Vasquez, Barbara Matusiak, Julia Kanno, Natalia Sokol, Justyna Martyniuk-Peczek, Sergio Sibilio, Yasuko Koga, Giovanni Ciampi, Marta Waczynska, Lighting conditions in Home Office and occupant's perception: an international study, Energy and Buildings (2022), https://doi.org/10.1016/j.enbuild.2022.111957, In press.