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The influence of façade and space design on building occupants' indoor experience

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A R T I C L E I N F O

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A B S T R A C T

Existing research on user's satisfaction at the workplace have shown that occupants' perceived comfort depends on a number of environmental and non-environmental factors and that forgiveness, meant as the indulgent attitude towards inadequate indoor environmental conditions, becomes an essential element in the ultimately rated level of appreciation of the indoor space. The aim of this study was to determine to what extent the building and façade design may affect a workplace as far as its occupants' perceived comfort and satisfaction are concerned. Data collected in an extensive post-occupancy evaluation conducted in four Swiss office buildings were used to specifically question the impact of their respective façade and space design. Despite sharing an equivalent environmental performance, these buildings differ substantially in terms of envelope designs, resulting in a heterogeneity of façade appearance and operability and thus a diversity of atmospheres inside the offices. Results revealed that aesthetical and emotional contribution brought by building design does indeed influence perceived comfort and satisfaction even when formal comfort-related environmental factors are the same. By introducing the concept of 'seasonal Forgiveness Factor', we could observe that higher ratings of the space and of the façade were strongly correlated with a higher level of tolerance towards possible criticalities of IEQ factors. The outcomes presented in this paper are expected to bring new insights and understanding to the multifaceted field of comfort and user satisfaction, while providing useful inputs to the façade and design industry.

1. Introduction

Rapid advances in design technology, along with international energy standards and rating systems, provide always more opportunities to architects and engineers to creatively achieve high scores regarding energy and environmental performance. Nevertheless, once occupied, some new buildings are charged with performing poorly in meeting users' need for comfort and satisfaction [1,2]. This phenomenon has been observed especially in office buildings, with a measurable impact on the employees' productivity [3,4] and on the building's ultimate operating costs [5,6].

Numerous field studies have concluded that design failures of this kind are often due to a confrontation of two realities: on the one hand, buildings are complex systems made up of physical and human elements and their many associations and interactions; on the

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other hand, comfort to be provided in buildings is often considered as the predictable result of a series of design decisions taken to deliver prescribed indoor environmental factors, without accounting for the broader psychological and behavioral aspects that it emanates from Ref. [7].

Over half a century, comfort research conducted with observations in climate chambers has been guided by the search for a universally applicable set of optimum comfort conditions primarily based on physiological models [8]. In the last 20 years, "real-world research" has highlighted the shortcomings of these models for the prediction of actual user satisfaction, especially for thermal comfort [9–11], thereby calling for more attention to the study of human satisfaction in real contexts and for broadening the comfort debate also to psychological and behavioral aspects [8].

1.1. Post-occupancy evaluations

Post-occupancy evaluations (POE) have had a major impact in this field, as they became increasingly acknowledged as an important instrument to measure building performance from the users' point of view and to provide further insights towards improving building design and management [7,12]. According to Meir et al. [13], POE can play a key role in determining "an acceptable balance between creativity and utility" in the building procurement process by assessing if and how design elements (including aesthetics) interact with elements of user satisfaction as well as with the actual functioning of the building.

As a complement to laboratory studies, which often try to isolate cause and effects with a risk of over-simplification or underestimation of context-dependent aspects of real spaces [3,14], many POE surveys have been able to highlight the inter-correlations between different environmental and non-environmental parameters. Research of this kind, revealed that non-environmental variables can induce occupants to extend their comfort zone by overlooking inadequacies of specific environmental conditions (i.e. people tended to be more tolerant towards their work environment) [4,15], and that IEQ perception can be influenced by e.g. the spatial layout of the workspace [16–23], the ventilation type of the building [4,15,24,25] and the level of personal environmental control (PEC) [16,21,26].

Besides the above-mentioned building design parameters, limited studies have specifically addressed the connection between building appearance and user comfort. In the late '70s, Fanger et al. [27] as well as Rohles & Wells [28] conducted climate chamber experiments to observe if factors such as room decoration and color of light had any influence on the perception of thermal comfort, though both of them concluded that no significant effect could be demonstrated. However, in a field study conducted in Malaysia, Kamaruzzaman et al. [23] found that the appearance of the building – including the attractiveness of the room, layout, privacy, management and external appearance of the building – belonged to the most significant group of factors for occupants' satisfaction, able in some cases to compensate possible situations of environmental discomfort.

Additionally, although not accounting for their interaction with environmental factors, a set of environmental design and psychology studies have documented that "beautiful spaces" (as opposed to "ugly spaces") could significantly affect people's perceptions and emotions [29,30]. Vilnai-Yavetz et al. [31] further explored this topic, showing a correlation between the aesthetics of a workplace and its occupants' satisfaction but not to their productivity.

Overall, these findings show that, while the role of pleasantness and emotional aspects of indoor spaces keeps coming back in the wider debate of occupant comfort, no clear evidence as yet been found about its actual impact, which raises the need for more systematic and detailed studies.

1.2. Façade design and user satisfaction

Considering their prominent responsibility of guaranteeing adequate indoor environmental conditions, building façades have always played a central role in the field of IEQ and energy research. Studies aimed at examining user comfort and behavior in relation to façade design and operation have usually focused on two main areas of investigation [32]: the preferred physical and luminous conditions in office environments, and occupant satisfaction and behavior towards the control of windows and shading devices.

Besides the main findings related to IEQ aspects, these studies have so far brought forward enough evidence to make two important statements. First, that some commonly held design assumptions regarding façades (e.g. that occupants generally prefer big transparent surfaces in their offices) can be proven wrong when not combined with proper comfort-control solutions [33]. Second, that a connection exists between the level of control and interaction that occupants establish with the building façade and their level of tolerance towards thermal and visual discomfort conditions in their workspaces [34–37].

Nevertheless, the way investigations (including POE) have looked at user satisfaction and behavior under different façade systems has been rather limited, and restricted to the consideration of single "conventional" façade components (regularly-shaped windows and common shading systems). Therefore, while quite robust conclusions can be inferred with regards to the influence of the operability level of conventional façade components on user's forgiving potential, existing literature seems to present a knowledge gap on this topic in the case of non-conventional façade designs, with almost no information on a potential influence of their aesthetics on the occupant's indoor experience. In fact, a study published in 2019 [38] highlights that while energy performance, along with indoor visual and thermal comfort, emerges today as an undisputed objective in contemporary façade design, solutions more suitable to providing customized aesthetic feature are those requiring further scientific efforts to determine their influence on the building occupants. A recent research that contributed to cover this gap through VR setting experiments [39,40], revealed that daylight patterns produced by different types of façade impacted both the subjective and physiological responses of people. In this study, the façade patterns not only consistently influenced the participants' spatial experience – such as how pleasant, interesting, exciting, calming, and complex the space was perceived – but also impacted spatial attributes that are traditionally considered objective, such as the perceived brightness, spaciousness, and satisfaction with the amount of view in the space. Moreover, the façade geometry significantly affected their heart rate, demonstrating that façade elements can have measurable effects on occupants. Findings of this type further demonstrate the necessity to investigate the influence of space and façade design on occupants' overall satisfaction, moving beyond aspects that are merely linked to comfort and energy efficiency, to embrace also the aesthetic dimension.

1.3. Aims and motivation

This paper focuses on the possible influence of façade and space design on building occupants' indoor experience by providing findings from a POE conducted in four office buildings characterized by different façade designs. While the environmental performance of the buildings and related level of users' satisfaction emerging from this study have already been described by the authors in a previous publication [11], the present contribution investigates the hypothesis that building and façade design may play a significant role in the indoor emotional and comfort experience at the workplace, and that a higher level of forgiveness towards poor environmental conditions can also be associated with spaces perceived as more pleasant.

2. Methodology

2.1. Description of the case studies and façades classification

The POE campaign was conducted in four office buildings located in Switzerland. The criteria for the selection of the four case studies were for them to be comparable in dimension, construction period, occupation and function, and ideally also performance. On the latter point, all the buildings had to have obtained the Minergie certification, a label attesting the high energy efficiency of new and refurbished buildings in Switzerland [41]. Note that this certification system relates primarily to the annual energy used by the building for heating, hot water and electrical ventilation, thereby requiring air-tight building envelopes and the use of an energy-efficient ventilation system.

From an architectural point of view, although workspaces of the four buildings are comparable in terms of size, layout and furniture, they distinctly differ in terms of their façade design. Two main criteria were used for the selection of façade types:(1) the type and level of users control on ventilation and daylight regulation; (2) the appearance of the overall non-opaque portion of the façade from the inside, i.e. the visual perception from the workstations. Based on these two criteria, buildings can be described as follows:

- Building 1 (B1) has regular-shaped windows and external venetian blinds. The building was conceived to have fixed, non-operable windows. Following employees' pressing requests for thermal conditions improvement, operable windows were installed though occupants are explicitly advised against opening them for energy management reasons.
- Building 2 (B2) presents a double-skin façade with a colored silk-printed patterns on the external pane and semi-transparent internal roller blinds.
- Building 3 (B3) has most of the offices overlooking internal courtyards which receive daylight from a fully glazed patterned façade and skylights. In some of the offices directly facing outside, windows can sporadically be operated through special keys designed for smoke and heat escape purposes.
- Building 4 (B4) has fixed glazing, sliding external shadings made of wire mesh and internal roller blinds on one facade. Offices are provided with hopper-type opaque elements that can be manually operated for natural ventilation. The opposite façade has conventional windows.

The main façade and ventilation system characteristics of the case studies are summarized in Table 1 and illustrated in Fig. 1.

Based on their appearance from the inside, i.e. on the visual perception from the workstations, the façades were hence classified as "conventional" and "unconventional". The first group refers to the presence of regularly-shaped transparent windows (fixed or operable) and commonly used shading devices, such as venetian blinds (Fig. 1 a, b, c). The second group includes custom-made design elements, such as patterns fully or partially covering its transparent portions, meant to provide an aesthetic identity to the façade and/or to be used as shading devices (Fig. 1 d, e, f).

Despite the initial identification of wider array of office buildings located in Switzerland responding to such prerequisites and presenting a diversity of non-opaque parts of façade, permissions to conduct a POE study were ultimately obtained only for the four case studies discussed in this paper.

Table 1
Case studies façade and ventilation system characteristics.

Building	Main façade systems and appearance	Ventilation system	Corresponding façade type in Fig. 1
B1	Ventilated façade with external venetian blinds.	Mainly mechanical. Windows are openable in most offices yet sometimes with restrictions.	a, b, c
B2	Double-skin façade with a colored silk-printed pattern on the external pane and semi-transparent internal roller blinds.	Mechanical only. Windows are non-operable.	d
B3	Double-skin façade with a chrome-based pattern on the external pane and internal roller blinds. Some offices have conventional glazing and venetian blinds.	Mechanical only. Most offices face internal closed courtyards preventing any air exchange with the outside.	e, c
B4	Floor-to-ceiling fix windows with external sliding wire mesh elements and internal roller blinds on the South façade. Conventional windows on the North façade.	Mechanical and natural. Offices facing South are provided with a hopper-type opaque element that allows for natural ventilation.	f, c

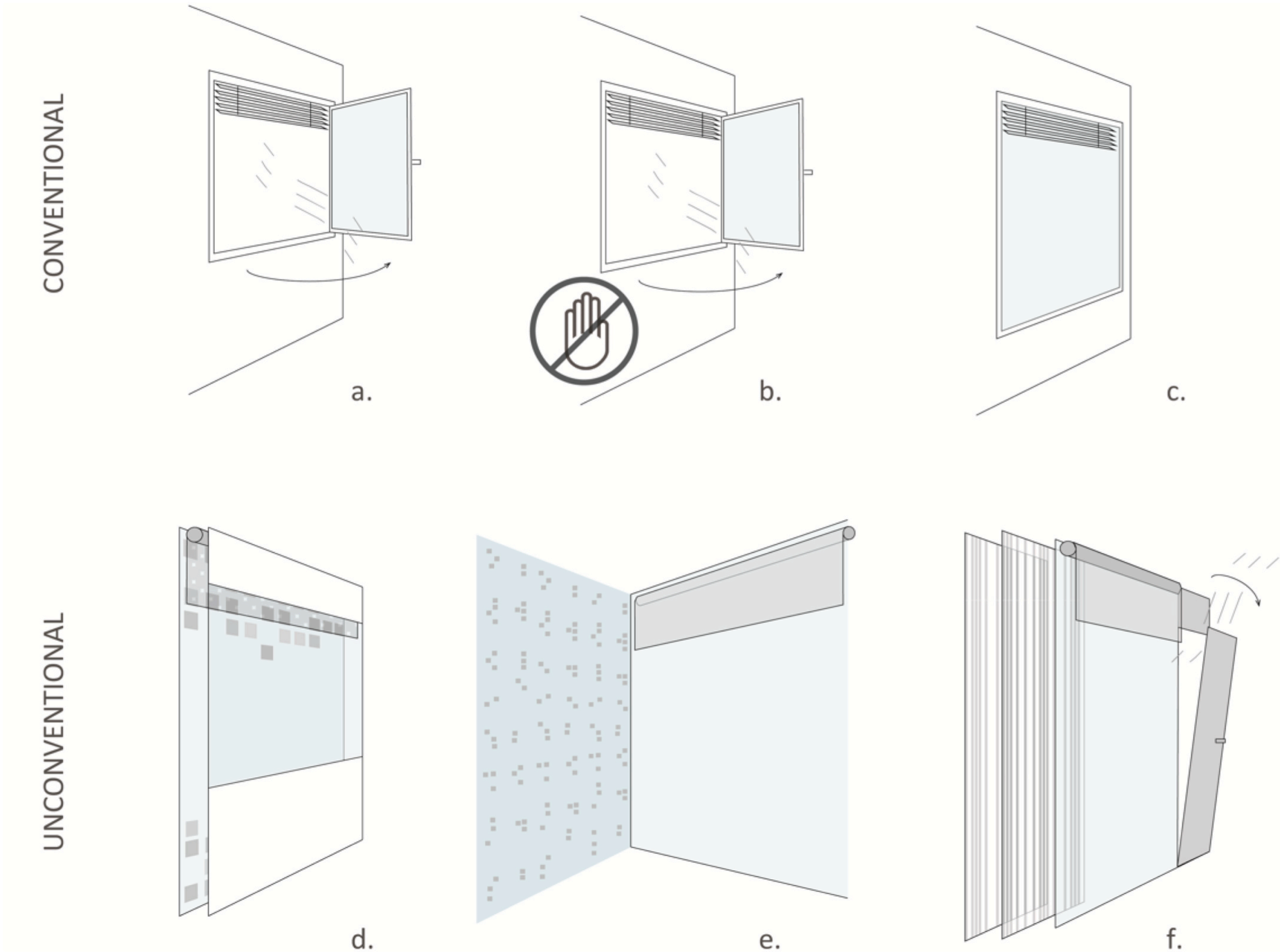

Fig. 1. Façade types analyzed in the study, as described in Table 1.

2.2. POE protocol and data collection

The POE was conducted twice during the year 2017: the first time at the end of the winter (March–April) and the second time at the end of the summer (September). The POE protocol consisted of:

- A two-week winter and summer continuous IEQ monitoring campaign (temperature, relative humidity and illuminance - data discussed in detail in Ref. [11]);
- Point-in-time IEQ monitoring episodes for instantaneous measurements (data discussed in detail in Ref. [11]);
- Point-in-time surveys (administered during the point-in-time measurements) for instantaneous comfort opinions (data discussed in detail [11]).
- Extensive surveys (one in winter and one in summer) to collect long-term comfort opinions;

284 answers were collected via the extensive survey and 269 via the point-in-time survey. Chi-square homogeneity test confirmed a homogeneous distribution of male and female participants for each building and season. Table 2 shows the distribution of answered extensive surveys per façade type of the occupants' office.

2.2.1. Indoor environmental monitoring

In each building, temperature and relative humidity data loggers as well as illuminance sensors were installed in selected work-spaces. The instrumentation was placed in order to have recordings taken at each floor and for each orientation. The loggers were typically installed on the users' desks in proximity of their workstations and measurements were taken by the loggers every 5 min. During the building site visits, portable equipment was also used to take point-in-time temperature, relative humidity and CO_2 ppm measurements at multiple locations across the floor levels. An HDR camera, a spot luminance meter and illuminance sensors were also used to sufficiently characterize the spatial and temporal variability of the visual environment experienced by the subjects.

2.2.2. Questionnaires

Buildings' occupants who agreed to participate in the research had to fill a preliminary background questionnaire to provide some personal information such as age, gender, work type, working hours per week, country of origin and duration of their living in Switzerland. An extensive on-line survey was sent to the buildings' occupants during the two periods of monitoring. The aim of the questionnaires was to investigate the level of satisfaction they had experienced during the two seasons with regard to comfort overall, IEQ factors (temperature, light, air quality and noise), view to the outside, privacy, personal control on the environment and self-rated productivity.

Ratings were registered through a 7-point Likert scale, with 1 corresponding to e.g. "Very dissatisfied" and 7 to "Very satisfied". Open questions to allow participant to add their own comments were also included in the questionnaire. Alongside point-in-time environmental monitoring episodes, occupants were asked to take short survey formats in order to link IEQ values with the related users' satisfaction. In this occasion, they were also requested to report how happy they were feeling in a scale from 1 to 5. Correlation tests allowed to exclude possible implication of their mood in the comfort rating. Participants could choose to have the questionnaires administered in English or in French.

In addition to comfort-related questions, several non-environmental questions connected to design aspects and perception of the space were included in the survey.

Participants were asked how much they liked certain aspects of the building's design, including their office's façade. They were also asked how interesting, exciting, calming, and pleasant the space was perceived by them and how much, in their opinion, the façade contributed to that condition.

These non-scalable properties of the lit environment (pleasantness, interest, excitement and calmness) were employed based on prior studies on perceptual effects of façade patterns in daylit conditions [39,40,42,43]. Whenever doubts emerged regarding the exact meaning of these terms for non-native English or French speakers, the following definitions from the Cambridge Dictionary were provided:

1. Pleasant: enjoyable or attractive.
2. Interesting: holding one's attention.
3. Exciting: making you feel excited.
4. Calming: making you feel peaceful, quiet or relaxed.

2.3. Evidence from a previous study and new hypotheses

Based on our previous study described in Ref. [11], and despite sharing similar energy-efficiency certification levels, the four buildings performed very differently in terms of meeting comfort expectations from their occupants. Although our measurements showed that the environmental factors seemed to comply with norm prescriptions in all the buildings, the indoor conditions never

Table 2
Distribution of answered surveys per façade classification.

Façade appearance	n.	Personal control on natural ventilation	n.	Personal control on daylight	n.
Conventional	107	Yes	54	Yes	98
Unconventional	177	No	202	No	74
		Some	28	Some	112

reached the targeted 80% user satisfaction threshold as can be observed in Table 3. In particular, temperature and air quality emerged as the most critical factors, with satisfaction rates never above 50% in three out of the four case studies.

On average, building B1 showed the worst behavior, with all factors except lighting reaching a satisfaction rate lower or equal to 40%, amongst which air quality was rated as satisfactory by only 16% of the occupants. B2 and B3 offered slightly higher levels of comfort – except for lighting that was rated least positively here – but with satisfaction rates that still remained below 50%. B4 seemed to offer better comfort conditions overall, but even there, we could see a dissatisfaction rate consistently above 25% for all the analyzed IEQ factors.

An intriguing observation, further discussed in Ref. [11], was that there seemed to be no correlation whatsoever between average comfort ratings by occupants (as satisfying vs. dissatisfying) and measured environmental factors. In many cases, the percentage of satisfied and of dissatisfied occupants were quite similar, which makes a clear identification of "good" vs. "bad" conditions almost impossible as occupants seem to disagree about them anyway. These findings suggest that metrics and criteria that merely address individual IEQ might not be able to fully capture the effect produced by the interaction of several environmental and non-environmental factors on the ultimate perception of comfort by users, inducing us to think that possible "forgiving" or "irritating" elements or conditions could actually play a role in the resulting occupant's satisfaction ratings. In this sense, the present contribution aims at disclosing:

- The possible influence of the façade design (including control strategies and appearance) on the comfort and indoor emotional experience;
- The possible impact of "forgiveness" based on space pleasantness and façade ratings;
- The possible influence of the façade appearance on the outdoor experience.

2.4. Data analysis and statistical methods

The statistical analysis was performed with the *R* software. Shapiro-Wilk tests and Q-Q plots revealed non-normal data distributions for all buildings, which supports the use of non-parametric regression for the statistical analyses. Mann-Whitney or Kruskal-Wallis tests were used to assess the statistical significance (NHST, Null Hypothesis Significance Testing) of the difference in two or more samples. Kruskal-Wallis test is a nonparametric method for testing whether samples are originated from the same distribution, extending the Mann-Whitney *U* test to more than two groups. The null hypothesis of the Kruskal-Wallis test is that the mean ranks of the groups are the same. Unlike the analogous one-way ANOVA, the nonparametric Kruskal-Wallis test does not assume a normal distribution of the underlying data, i.e. is more suitable for non-normally distributed data (e.g., ordinal or rank data).

When a significant effect was found in the Kruskal-Wallis test (more than 2 samples), a post-hoc test using the Mann-Whitney test with a Bonferroni correction was applied to check the statistical significance of the difference between pairs of groups. For both Kruskal-Wallis and Mann-Whitney tests, results were declared statistically significant when the probability that a difference could have arisen by chance was below 5% ($p \leq 0.05$). To infer whether the differences detected have any practical relevance, the effect size was also estimated through the formula: $r = z/\sqrt{N}$ [44], where N is the total sample size.

In interpreting effect size (r), benchmarks were used to indicate low ($r \geq 0.20$), moderate ($r \geq 0.50$) and high ($r \geq 0.80$) effect size/correlation. Values < 0.20 were considered negligible, therefore excluding the variable to have any relevant effect. This interpretation is based on Fergusson's scale [45], which happens to be stricter than the one suggested by Cohen (also largely used in this field of research), so as to confer a higher degree of confidence on our results.

3. Results

3.1. Influence of the façade control on the comfort experience

To test whether the façade system and in particular the personal control on window opening and shading operation could have had an influence on the building users' comfort perception, Kruskal-Wallis statistical tests were conducted. As can be seen in Fig. 2 (left), the statistical analysis showed indeed that different levels of personal control on natural ventilation significantly affected satisfaction with temperature (p-value = 0.0004) and air quality (p-value = 0.0000) as well as with overall comfort (p-value = 0.0000), with an effect size always of practical relevance ($r \geq \pm 0.20$). Conversely, a small p-value combined with a non-significant effect size allowed us to exclude any effect of control of natural ventilation on satisfaction with acoustic conditions.

The amount of control on shading devices resulted to be statistically significant for lighting satisfaction ratings (p-value = 0.0000, $r \geq 0.20$), but not for overall comfort or temperature satisfaction (Fig. 2, right).

In general, results showed that occupants who had a higher degree of personal control in the regulation of natural ventilation or of

Table 3
Satisfaction rates of the comfort factors based on the long-term assessment of the four buildings. The question asked was in this case: "On a scale from 1 to 7 (1 = very dissatisfactory, 7 = very satisfactory), how would you rate the [temperature]/[air quality conditions]/[light conditions]/[acoustics conditions]/[view to the outside] you have experienced in your office?". The 'satisfaction' threshold is placed at level 5 (i.e. % satisfaction applies to ratings 5 to 7).

	Overall Comfort	Temperature	Air Quality	Lighting	Acoustics
B1	38%	29%	16%	69%	40%
B2	56%	49%	44%	59%	37%
B3	40%	26%	25%	45%	62%
B4	82%	49%	75%	63%	72%

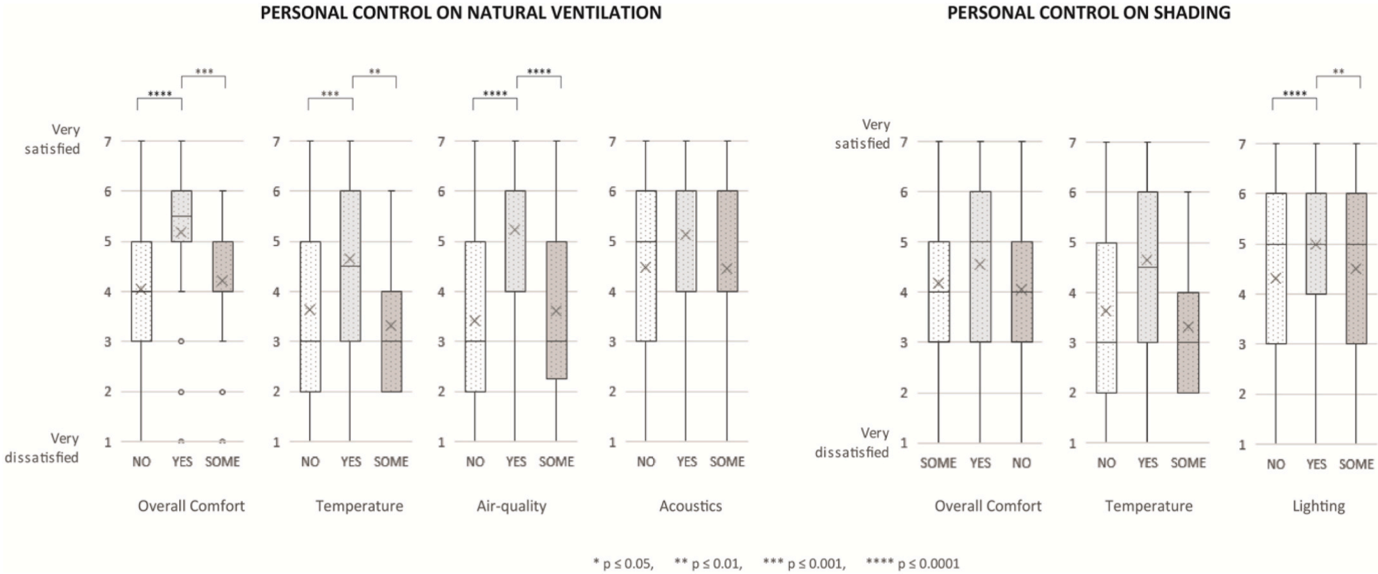

Fig. 2. Box plots showing the rating distributions for overall comfort, temperature, air quality and acoustics based on the level of personal control on ventilation (left) and for overall comfort, temperature and lighting based on the level of personal control on shadings (right). Differences between groups of level of control (NO, YES, SOME) are reported when p-value ≤ 0.05 and effect size $\geq \pm 0.20$.

solar radiation through façade components tended to have, on average, a more positive comfort perception.

3.2. Influence of the façade appearance on indoor emotional and comfort experience

Participants to the POE were also asked how much they liked certain aspects of the building's design, with a particular emphasis on the façade. Amongst others, they were first asked about their general appreciation of the façade on a scale from 1 ("I don't like it at all") to 7 ("I like it very much"). One of the first interesting results was that, as shown in Fig. 3, people working in office spaces with an unconventional façade tended to like their façade significantly more than occupants sitting in spaces with conventional ones (p-value = 0.0000; r = −4.13) (see Fig. 4).

Building users were subsequently asked to express their opinion on how pleasant, interesting, exciting or calming their office space looked on a scale from 1 ("not at all") to 7 ("very much") and also to estimate to what extent that emotional experience could be attributed to the façade itself. Based on the proportion of positive answers (i.e. ratings between 5 and 7 about the office space being pleasant, interesting, exciting or calming), it appears that for buildings with conventional façade types, the façade contributed the least to the aesthetical and emotional perception of the space, whereas patterned glazing as well as metal wire mesh skins seemed to participate significantly to the emotional atmosphere of the workspace, resulting in higher rates for pleasantness (p-value = 0.0003, r = - 0.21), interest (p-value = 0.0004, r = - 0.21) and excitement (p-value = 0.0009, r = - 0.20), and no significant difference for calmness (p-value = 0.01681, r = - 0.14).

This finding becomes particularly interesting if we associate it with answers regarding the importance of these factors to occupants, reported in Fig. 5. Participants were here asked to rate how important the previously mentioned comfort and emotional factors had been for their well-being and productivity on a scale from 1 ("not at all") to 7 ("very much"). IEQ factors votes ranged from 2 to 7 with average and median values always above 5; note that the pleasantness of the space was never considered unimportant and registered average and median values comparable to those of IEQ factors (between 5 and 6). Statistical tests revealed that an interesting, exciting and calming space was instead attributed a lower level of importance compared to the other factors (p-values <0.0001, r > ± 0.20) but not when compared among them. All emotional factors were, however, consistently considered important both for well-being and for productivity, with average and medium rates always above the neutral vote. Interestingly, access to views to the outside was judged as important as environmental factors and pleasantness of the space when it came to the respondents' well-being, but less important with regards to their productivity (p-value <0.0001, r > ± 0.20).

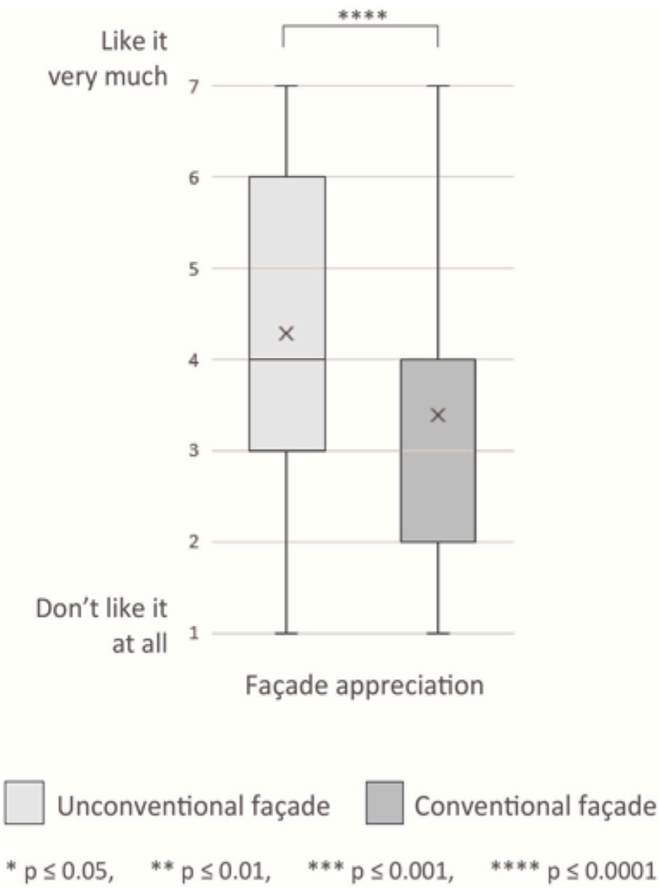

Fig. 3. Box plots showing the distribution of answers related to the façade appreciation based on the façade type.

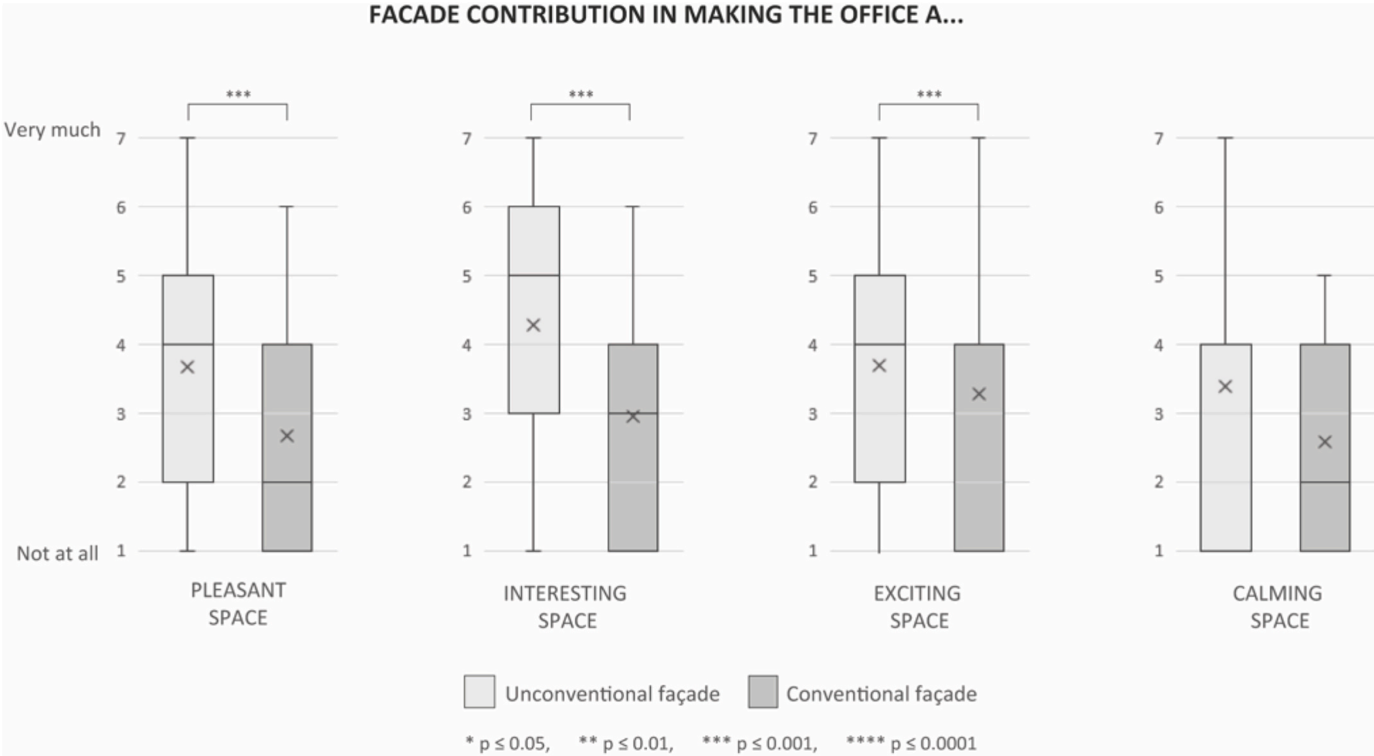

Fig. 4. Distribution of answers about the façade contribution in the aesthetical and emotional experience of the office space based on the façade type (Conventional, Unconventional). Only answers of respondents who had attributed a vote from 5 to 7 to the previous questions "How much does the space of your office look [pleasant]/[interesting]/[exciting]/[calming]?" were taken into account for this analysis. Differences between the two façade types are reported when p-value ≤ 0.05 and effect size $\geq \pm 0.20$.

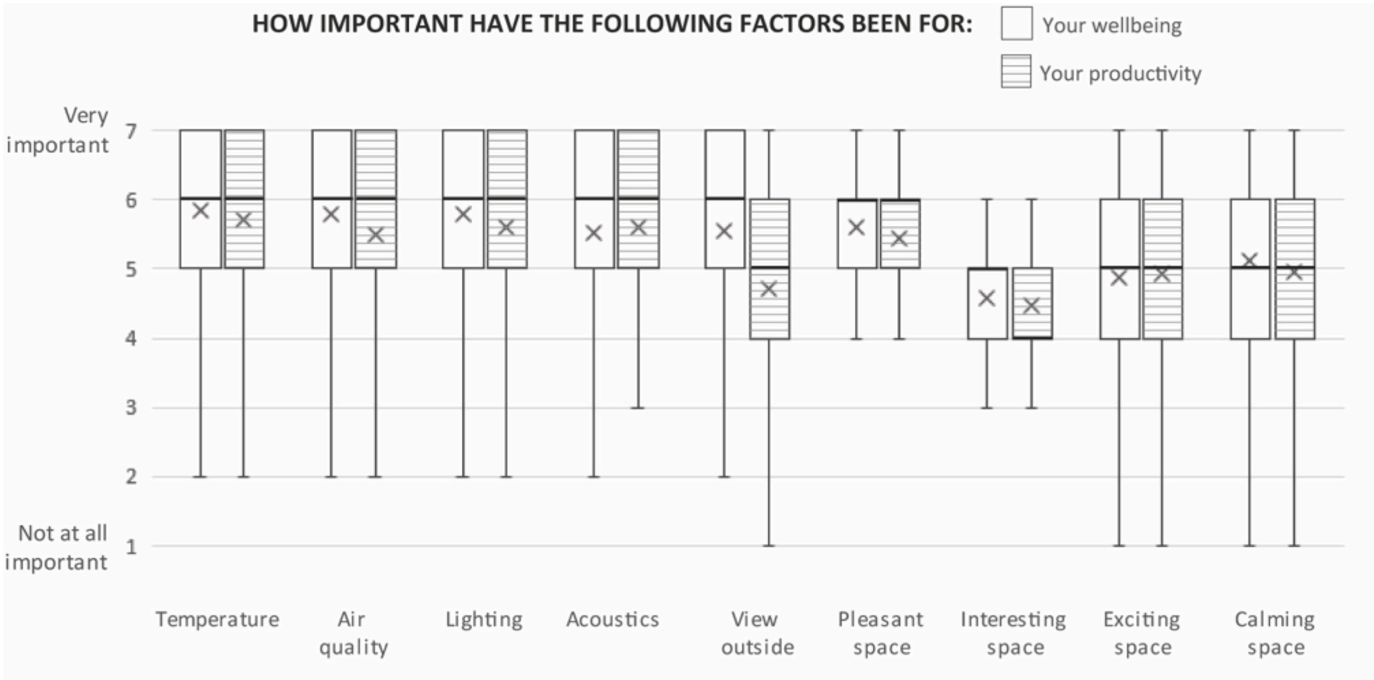

Fig. 5. Distribution of ratings on the importance of comfort and emotional factors for the respondents' well-being and productivity.

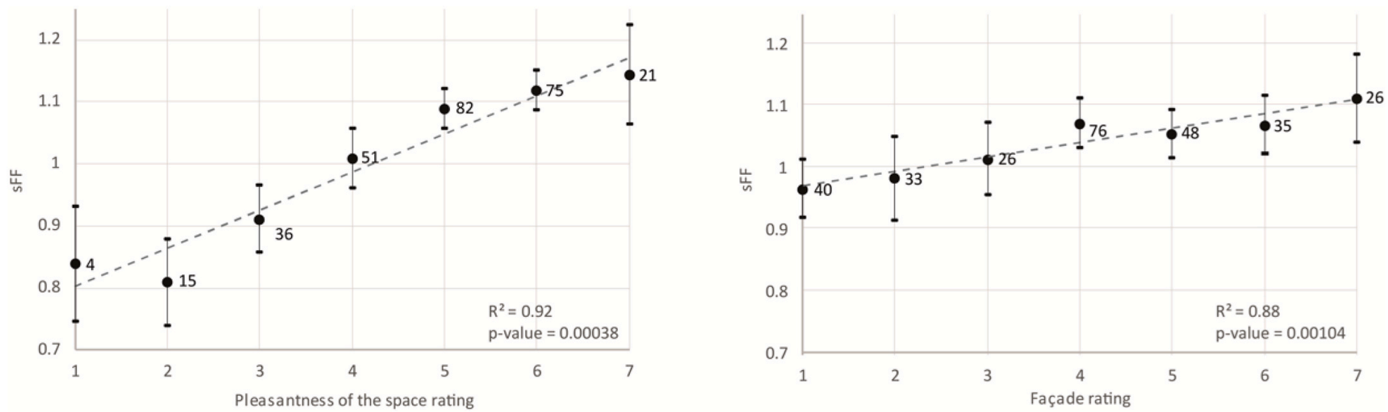

Fig. 6. Relationship between the seasonal Forgiveness Factor (sFF) scores and Pleasantness rating (left) or Façade ratings (right). Numbers next to data points represent sample size for weighted linear regression model. Error bars represent standard error.

3.2.1. Impact of forgiveness

To assess whether and to what extent design variables could have induced occupants to extend their comfort zone by overlooking inadequacies of specific environmental conditions, a forgiveness factor was calculated, and possible correlations to space pleasantness and façade ratings were tested.

The notion of a forgiveness index has been introduced already by Leaman & Boardass [16] in their Building Use Studies (BUS), by deriving it as a ratio of Overall Comfort score to the average of the scores for the six environmental factors: Lighting Overall, Noise Overall, Temperature Overall in both winter and summer, and Air Overall in both winter and summer. This index purports to quantify the user's tolerance of the environmental conditions in the building, with values greater than unity taken to indicate occupants being more tolerant, or 'forgiving' of a building's thermal environmental conditions.

This approach was described Leaman & Boardass through Eq. (1):

$$FF = Comfover / ((AirW + AirS + TempW + TempS + Light + Noise)/6) \quad (1)$$

The nature of this formula is derived from the type of survey used in BUS campaigns, designed to collect occupants' year-round comfort opinions, with a seasonal distinction regarding temperature and air quality. The BUS protocol (and hence the forgiveness factor calculation) thus assume an effect of season and a greater influence (compared to the other variables) of temperature and air quality on overall comfort.

As mentioned in section 3.1., however, this assumption was found not to be true for this research, which explicitly investigated both the effect of season and the relative influence of the different IEQ variables.

To address 'forgiveness' in this study, we thus defined a seasonal Forgiveness Factor (sFF) to be able to look at a possible forgiving effect separately in winter and summer.

The sFF was calculated as follows (2):

$$sFF = Comfover / ((Air + Temp + Light + Noise)/4) \quad (2)$$

Responses related to the pleasantness of the space and the appreciation of the façade were binned according to the rating item (from 1 to 7). A linear regression model, weighted according to the number of seasonal Forgiveness Factor samples within each bin, was then fitted to test possible correlations between the sFF scores and these two design factors. As can be observed in Fig. 6, the regression model showed a strong positive correlation with both the pleasantness of the space rating ($R^2 = 0.92$, p-value = 0.00038), and the façade rating ($R^2 = 0.88$, p-value = 0.00104). This result suggests that higher levels of appreciation of these two design factors led to a higher level of tolerance towards the environmental quality of the workspace.

Statistical tests did not reveal any influence of season or gender in the seasonal Forgiveness Factor score.

3.3. Influence of the façade appearance on the outdoor experience

Another set of questions in the survey enquired about the occupants' appreciation of the façade as an architectural element characterizing the overall building aspect. In particular, they were asked to express their level of agreement with the following statements:

1. I like the façade because it makes the building unique and very recognizable from the outside.
2. I like the façade because it embodies a spirit of innovation.
3. I like the façade because it embodies the values of the company for which I work.
4. I like the façade because it embodies the values of sustainability and respect for the environment.

Fig. 7 shows that answers to the statement n. 3 and 4 did not differ significantly from one building to another (p-values > 0.5 in both cases). Instead, the level of agreement on the façade appreciation for its contribution to the uniqueness and recognizability of the building (statement n.1) and the spirit of innovation it embodies (statement n.2) were found to be statistically different when comparing B1 and B2 (p = 0,00002, r = - 0.59 for statement n.1; p = 0.0064, r = - 0.42 for statement n.2), B1 and B3 (p = 0.00002, r = −0.43 for statement n.1; p = 0.0032, r = −0.32 for statement n.2), and B1 and B4 (p = 0.00064, r = −0.44 for statement n.1;

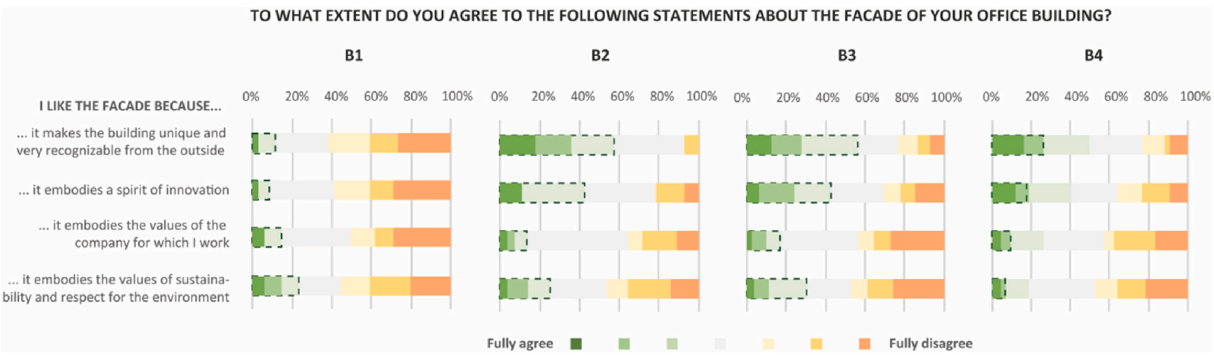

Fig. 7. Levels of agreement in the four buildings for the statements related to possible reasons of appreciation of the façade.

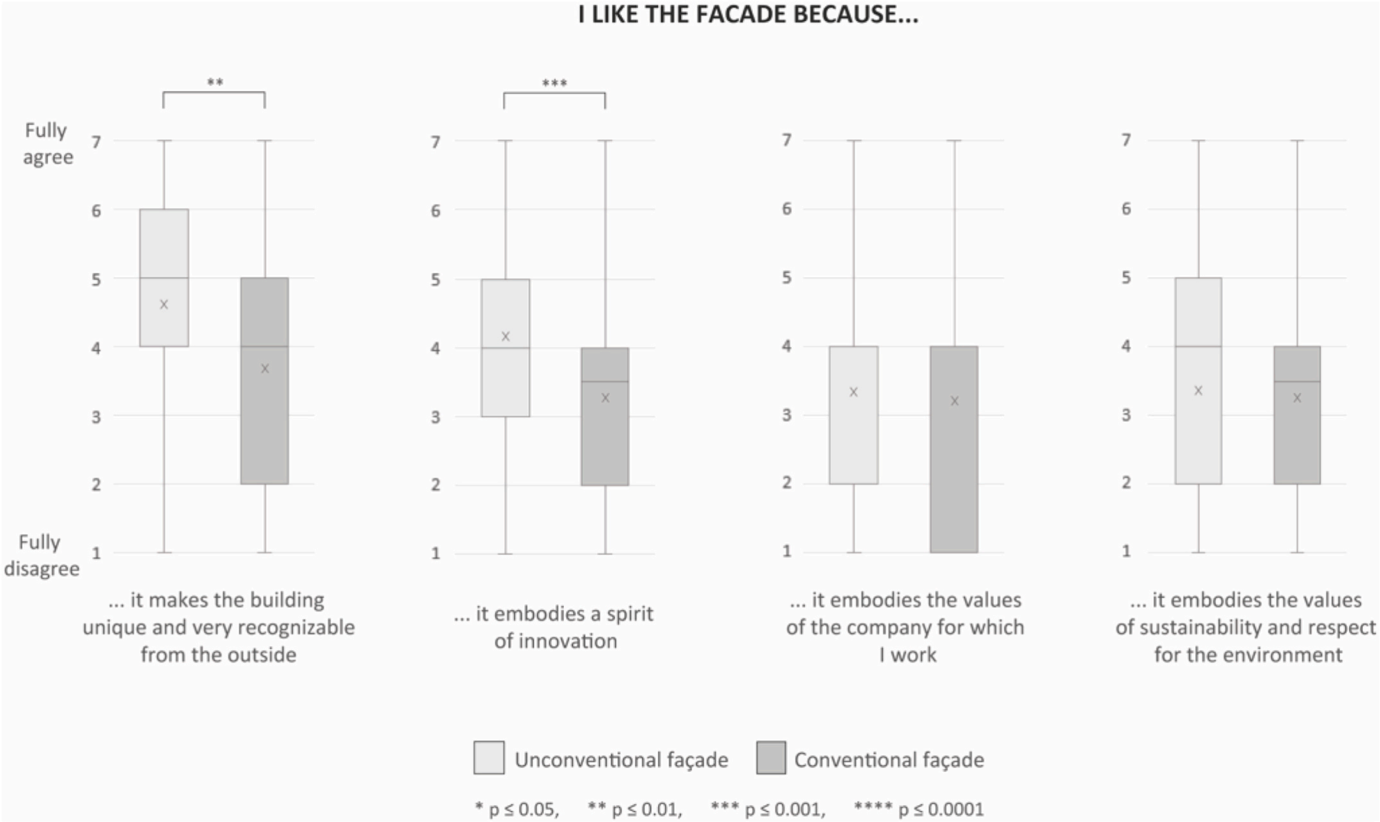

Fig. 8. Box plots showing the distribution of answers related to the reasons of façade appreciation based on the façade type.

p = 0.0228, r = −0.33 for statement n.2).

Looking at the agreement proportions based on façade types (Fig. 8), a statistically significant difference can be observed between conventional and unconventional façades in statement n.1 again (p-value = 0.00101, r = −0.24) and in statement n.2 (p-value = 0.0004, r = −0.26), meaning that unconventional façades tended to be more appreciated than conventional facades with respect to their contribution to the appearance of the buildings and the sense of innovation they convey. No difference was observed for statement n.3 and 4 in this case (p-values > 0.5).

Statistical tests were also conducted to check a possible relation with the level of personal control and the appreciation of the façade for the values of sustainability and respect for the environment it may embody, but no statistical evidence was found about these aspects.

4. Discussion and conclusions

This paper discusses the results of a POE campaign focusing on indoor comfort, with a dedicated emphasis on the influence of non-environmental factors on perception of comfort or satisfaction with the space in general. The motivation behind this emerged from the observation, based on the same POE [11], that perceived indoor comfort assessed through surveys sometimes greatly differs from comfort predictions based on measured IEQ parameters, hence pointing out at the limitations of traditional comfort metrics to properly account for the possible impact of non-environmental factors on the ultimate users' physiological and psychological perception of their work environment.

Despite being somewhat limited in its scope and dimension, the present study provides new insights on the role that façade design and space appearance can play on occupants' comfort and their satisfaction with a workplace.

In particular, results from this research can be summarized as follows:

- In workspaces with comparable measured environmental parameters, the amount of personal control on façade operation was found to correlate with the perception of the indoor environmental quality. More specifically, a higher degree of control on windows opening could be associated with a higher satisfaction with overall comfort, temperature and air-quality, while a higher control on shading devices led to greater satisfaction with lighting.
- People tended to appreciate the façade of their office building more when aesthetical elements were present. Compared to conventional façades, patterned envelopes seemed to contribute to a larger extent also to the aesthetical and emotional perception of the indoor space and were associated to a greater ability in providing a unique and recognizable aspect to the building and in reflecting a spirit of innovation.
- For both wellbeing and productivity aspects, working in a pleasant space was found as important as working in an environmentally comfortable place. Being in an interesting, exciting or calming workspace was considered important too, but less than being in a comfortable one (based on IEQ factors) or in a pleasant one.
- Finally, a strong correlation was found between the seasonal Forgiveness Factor and the pleasantness of a space as well as the appreciation of a façade, which supports the hypothesis that occupants who like their office and its façade may have a good perception of their overall comfort for a larger range of environmental conditions. This would therefore suggest a possible link between occupant satisfaction and building aesthetics and would confirm that the development of a more or less forgiving behavior is essential to determine the ultimate level of comfort and acceptability of the indoor space.

Therefore, besides confirming that the amount of personal control on façade operation can have an impact on the occupants' perception of the indoor environmental quality, the surveys conducted in this study - when it comes to aesthetical features - revealed that workspaces evoking a certain atmosphere and aesthetics can be beneficial for perceived comfort, well-being and productivity of employees and that façade design can indeed play a role towards this end.

The outcomes presented in this paper bring therefore new insights to the façade design sector and are encouraging for further efforts to be dedicated to deepen our understanding of what lies behind the comfort and satisfaction of buildings' occupants.

As research increasingly embarks into interdisciplinary and multi-factor studies to observe the interaction of multiple variables on the psychological and physiological experience of a space, findings from this study confirms that future evaluations of buildings through POEs should extend their range of observed performance factors and design items, by incorporating both environmental and non-environmental components. Changes of this kind in POE approaches can be even more relevant at the present time in light of issues that have emerged following the spread of the COVID–19 virus and the related necessity, for the workplace and building design in general, to account for a re-contextualized notion of people comfort, productivity, health and safety.

Author statement

Luisa Pastore: Conceptualization, Methodology/Study design, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Project administration. **Marilyne Andersen:** Conceptualization, Resources, Writing – review and editing, Supervision, Funding acquisition.

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.

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