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DOI

[10.1016/j.buildenv.2021.108742](https://doi.org/10.1016/j.buildenv.2021.108742)

Publication date

2022

Document Version

Final published version

Published in

Building and Environment

Citation (APA)

Ortiz, M. A., & Bluysen, P. M. (2022). Profiling office workers based on their self-reported preferences of indoor environmental quality and psychosocial comfort at their workplace during COVID-19. *Building and Environment*, 211, Article 108742. <https://doi.org/10.1016/j.buildenv.2021.108742>

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Profiling office workers based on their self-reported preferences of indoor environmental quality and psychosocial comfort at their workplace during COVID-19

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ARTICLE INFO

Keywords:

Workplace
Preferences and needs
Health and comfort
COVID-19

ABSTRACT

Due to the COVID-19 pandemic, a large number of office workers were required to conduct their work from home. Little is known about the indoor environmental quality (IEQ) preferences and psychosocial comfort preferences of staff working from home. Therefore this study aimed to cluster office workers working at home based on their self-reported preferences for IEQ and psychosocial comfort at their most used workspace and to identify these preferences and needs of workers during the COVID-19 pandemic. A questionnaire was administered to employees of ten offices in the Netherlands, and the 502 respondents were clustered with two models by using TwoStep cluster analysis. The first model was based on variables related to IEQ preferences, while the second was to psychosocial comfort preferences. The analysis revealed four IEQ clusters and six psychosocial comfort clusters. Comparison of these results with other similar studies proposed that the prevalence of anxiety, depression, migraine, and rhinitis, increased for this population during the work-from-home period of the pandemic. Further results suggest that both IEQ and psychosocial comfort preferences are situation- and gender-dependent.

1. Introduction

Office workers spend a large part of their time behind a desk, performing activities such as writing, reading, calling, and since COVID-19, having online meetings with their peers. In fact, during the lockdown period at the end of 2020, and also before it, many office workers in the Netherlands were working from home. The workplace, whether at home or in an office building, should therefore ensure comfort, health, and wellbeing. Previous studies on healthy and comfortable indoor office environments have shown how complex relationships between indoor building conditions and human health and well-being are [1–11]. There are many indoor environmental stressors (e.g. thermal factors, lighting aspects, odours, moisture, mould, noise and vibration, radiation, chemical compounds, particulates), that can cause their effects additively or through complex interactions. These effects can be influenced by other factors and stressors than the environmental parameters used in guidelines, whether of psychological, physiological, personal, social, or environmental nature. This cocktail of stressors that people are exposed to changes over time, while the exposure is also influenced by past exposures and interactions that occur between those stressors.

It is observed that the most influential environmental aspect can differ per study, for example, the amount of space and acoustics in Ref. [12], air quality in Refs. [13,14], thermal environment in Refs. [15–19], privacy and acoustics in Ref. [20], and acoustics and office layout in Ref. [21]. Reasons for these differences may be the study design (e.g. building type, location and construction date) [7,22], or social-cultural factors [15,23]. In addition to that, both the physiological perception of IEQ-aspects and the psychological perception of social comfort aspects can contribute to satisfaction with the physical environment [24]. Both the perception of social comfort and that of IEQ may vary between individuals, due to differences in reactions and sensitivity [25]. For example, the dependency of visual comfort on the sophistication of the visual system and the expectations of the occupant [26]; the relation of willingness to discuss control of the indoor environment to personal traits [27]; and the relation of satisfaction with the physical environment to individual differences in privacy needs [28].

Moreover, people experience and complain about certain building-related symptoms even when their workspaces comply with the guidelines [7,29]. Current available guidelines, standards, and tools for a good indoor environmental quality (IEQ) (such as BREEAM, WELL and

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<https://doi.org/10.1016/j.buildenv.2021.108742>

Received 9 November 2021; Received in revised form 15 December 2021; Accepted 29 December 2021

Available online 1 January 2022

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LEED), are all based on single dose-response relationships to prevent (negative) health and comfort effects. The indoor office environment with occupants is clearly a complex system, in which many IEQ factors show non-linear relations with both satisfaction and health effects that can differ per situation [30,31]. Nevertheless, IEQ is still usually assessed mainly by dose-related indicators, based on linear single dose-response relationships for negative stressors, expressed in number and/or ranges of numbers for each of the factors (indoor air, lighting, acoustics, and thermal aspects), developed for the average occupant. Ignoring that we are dealing with individuals in different situations (e.g. sitting behind a desk, in a meeting room listening, on the phone). Ignoring other stressors (physical, physiological, personal, psychological, and social) and their integrated effects over time; and ignoring interactions between stressors in complex, real-life exposure situations at environment level and interactions between various body responses to exposure(s) at the human level.

Therefore, recently, an integrated analysis approach was introduced, which takes account of the combined effects of various (positive and negative) stressors and includes occupants' preferences and needs as well as interactions at the human and environmental levels [29]. With this integrated analysis approach, it is possible to match different profiles of people with different patterns of positive and negative stressors for a certain situation, instead of linking indoor environmental conditions to the average comfort and health of a large population. Profiling occupants based on their comfort and the needs of IEQ in certain scenarios and situations is an essential part of this approach.

Profiling or clustering of occupants based on their behaviours and preferences has been performed in several studies with different methods. The K-mean clustering algorithm was used to profile occupants based on their lighting control behaviours and dimming level preferences [32]; on electricity load patterns [33], HVAC-schedules [34] and thermal preferences [35]. More recently, TwoStep clustering has been applied on clustering of primary school children in the Netherlands based on their preferences and needs of IEQ in their classrooms [36]; home occupants in the Netherlands based on their comfort behaviours and energy use pattern [37,38]; office workers based on their self-reported health and comfort [39], on control of indoor climate [27], on comfort related to activities [40]; and outpatient workers based on their self-reported comfort and preferences of IEQ and social comfort in hospitals [41]. All of the studies listed above clearly indicate that people can indeed differ in their perceptions, preferences and needs and that it seems possible to distribute them into clusters (profiling).

In a previous study on self-reported health and comfort of office workers from the OFFICAIR study in the Netherlands, TwoStep cluster analysis revealed three profiles of occupants: *Healthy and satisfied* workers, *Moderate healthy and noise-bothered* workers, and *Unhealthy and Air and temperature-bothered* workers [39]. While the first group was by far the healthiest, significant higher risks for building-related symptoms such as dry eyes, dry skin, and watering, itchy eyes were identified for the unhealthy group than for the moderate healthy group. The outcome confirmed, that there is a need for an integrated approach to better understand the different office workers, in particular, *the moderate healthy and noise-bothered workers* and *unhealthy and air and temperature-bothered workers* to be able to provide customized solutions for their complaints. Further studies were recommended as the study included a few limitations. First, since the profiles of office workers in that study were created mainly through the analysis of self-reported complaints, it would be beneficial to include additional information such as user preferences, needs, and control behaviours for further studies when designing their data-gathering stage. More specifically, several recent studies [37–39,41] have shown that users' needs and preferences are key items for determining final clustering models of school children and home occupant archetypes. It is therefore expected that these items are also important for enhancing the identification of office workers' profiles.

In a study with 556 outpatient workers in six hospital buildings,

TwoStep cluster analysis resulted in six clusters for IEQ preferences and comfort and three clusters for social aspects preferences and comfort [41]. The limited overlap of the profiles of the IEQ clusters with the profiles of the social clusters suggested that it is important to study both simultaneously. Additionally, for both cluster models, the relations with building-related aspects were limited, suggesting that outpatient staff members did not relate their preferences to the actual building where they work.

Due to the shifting nature of the IEQ studies towards identifying models of users preferences, needs, and perceptions, related to social comfort and IEQ, and the shift towards working from home during the COVID-19 pandemic, the aim of this study is two-fold: 1) to cluster office workers based on their self-reported preferences of IEQ, and based on their self-reported preferences of social comfort at their workplace, whether at home or the office and 2) to study the preferences and needs of workers during the COVID-19 pandemic.

2. Methods

2.1. Study design

In the first week of December 2020, office workers from ten organizations (each of which normally occupies one building) were sent an e-mail inviting them to participate in an online questionnaire about their preferences for different IEQ elements of their workplace at home or the office.

2.2. Recruitment of office workers

In the spring of 2020, 17 organizations, totalling around 1635 potential office workers participants, were approached to inquire on their willingness to take part in the questionnaire. Ten of the organizations agreed to join the survey, which was held at the end of 2020. The participating organization consisted of the following: two faculties of the Delft University of Technology, one architectural firm (cc. 200 employees), one contractor (cc. 300 employees), three small engineering consultancies (40–70 employees), one large engineering consultancy (cc. 200 employees), and two branch organizations (cc. 25 employees each).

2.3. Questionnaire

The questionnaire was developed based on those previously developed and validated by Bluyssen et al. (2016) [7], Eijkelenboom et al. (2020) [41], and Ortiz et al. (2018) [37] and is composed of eight sections: personal information, lifestyle, IEQ preferences, psychosocial comfort preferences, IEQ perception, control and satisfaction, and health.

The questionnaire was developed in English, then translated into Dutch. Then, it was pilot-tested with participants in both languages, out of which an improved version was developed, especially in terms of its flow and certain semantic problems. Once improved, the updated questionnaire was pilot tested again in the two languages. The final version of the questionnaire was available to participants in the two languages, so they could choose the one they felt most comfortable with.

Concerning health status, participants were asked: "Did you suffer from the following condition in the last year?". The following conditions were included: COVID-19, asthma, bronchitis, wheezing, other respiratory problems, hay fever, rhinitis eczema, dermatitis, other skin conditions, high lipids, diabetes, high blood pressure, other heart conditions, migraine, depression, anxiety, psychiatric problems, and other conditions.

For environmental conditions, participants were asked: "How would you describe the typical indoor conditions in your most-used workplace during the past month?" These questions were answered by the workers with a seven-point scale. For control and satisfaction, they were asked:

"How much control do you personally have over the following aspects of your working environment?" on a scale from 1 (no control) to 7 (full control): temperature, ventilation, shading from sun, lighting, and noise. For satisfaction with your workplace: "How satisfied are you with the following in your most-used workplace?" on a scale 1 (unsatisfactory) to 7 (satisfactory) (amount of privacy, layout, decoration, cleanliness, view to outside). For both the IEQ and the psychosocial comfort-related aspects, the question "Please rate on a scale from 1 to 10, the importance of each of the following aspects for your work performance at your most-used workplace" (1: Not important at all; 10: Extremely important) was asked. IEQ preferences comprised of: ventilation and air freshness, temperature, the temperature of my feet, temperature of chair, presence of windows, sounds from inside, sounds from outside, smells, artificial light, and natural light. Psychosocial comfort preferences comprised of storage, cleanliness, amenities (desk, monitor, etc.), chair type, presence and company of others, size of the room, identifying with the place, control the place, and privacy. Then, for the importance of items to work better at one's workplace, it was asked: "Please rate on a scale from 1 to 10, the importance of each of the following items that would help you to work better", where 1: Not important at all; 10: Extremely important (items: chair seat heating, chair backrest heating, desk heating, desk lamp, personal ventilation and fresh air at the desk, control of surrounding sound, control of shading in room, control of ventilation in the room, control of temperature in the room, headphones, and presence of plants).

2.4. Procedure

One week before the digital invitation with the link to the questionnaire, each office worker received an information e-mail from the management of their organization, announcing the survey and its purpose. It was emphasized that the information gathered would be treated confidentially and that participation was voluntary; such measures were once again highlighted in the consent form of the questionnaire. In the week of the survey, each office worker received an invitation from the management of the organization with a link to the online questionnaire which was developed with the Qualtrics XM platform. It was emphasized that the survey is anonymous and that they were allowed by management to complete the survey during their working hours at their workplace (whether at home or the office). One week later, a reminder was sent and the survey was closed after two weeks.

2.5. Ethical aspects

The Ethics committee of the Delft University of Technology approved the study on June 26, 2020. A data manager from the Delft University of Technology assessed data security. To respect the privacy of the participants, measures were taken for the protection of contact information, safe data storage, and withholding of personal information, such as email addresses and IP addresses. The first page of the link to the questionnaire informed the participants that by completing the questionnaire, they would give their consent to use their responses for research purposes. At the end of the questionnaire, a submit button had to be confirmed by the participants to include their responses in the study; therefore, only those who confirmed were included. Participants were able to skip any question they would not feel comfortable with. To decrease involuntary missing answers, an automatic check of completeness was performed, and missing answers were signalled to the participant at the end of each page of the questionnaire.

2.6. Data management and analysis

All data were digitally completed and exported from the Qualtrics XM platform to IBM SPSS statistics 26 (SPSS Inc., Chicago, IL, USA) for analysis of the data. First, the data for the respondents whose progress was less than 80% were filtered out. Descriptive statistics such as

percentages, range (minimum-maximum), arithmetic mean with standard deviation (SD) were used to summarize office workers' characteristics, health, symptoms, psychosocial comfort, IEQ preferences. Finally, Chi² tests were performed with the variables from each group, to ensure that no statistically significant difference existed between groups so that all individual datasets could be pooled together into a single dataset.

Once the data were pooled, before performing the TwoStep cluster analysis and to statistically strengthen the models, Principal Component Analysis (PCA) was conducted with the psychosocial comfort variables and the IEQ preferences variables, to reduce the number of original variables (9 and 10 respectively) into fewer independent components. Therefore, the Eigenvalue to determine the components was greater than 1; sample adequacy with Kaiser-Meyer-Olkin was greater than 0.6, and a Varimax orthogonal rotation was selected. For the TwoStep analysis, the final two sets of components resulting from the PCA were used to conduct the analysis twice, once with the IEQ preferences factors and once with the psychosocial preferences. This clustering technique was used as opposed to other clustering methods, as it allows for the handling of both continuous and categorical data. Final model validation was carried out with the fulfillment of four conditions: a silhouette of above 0.2; variables predictor importance greater than 0.02; ensuring statistical significance between variables by conducting Chi² tests; applying the model to two random halves of the sample and ensuring that the results are similar.

3. Results

3.1. Participation rate and characteristics of the study respondents

Table 1 presents the number of office workers who were invited and responded per participating organization. From the total 1729 invited office workers from the 10 participating organizations, 502 completed questionnaires were received, which means a response rate of 29%. Among the 502 respondents who submitted a questionnaire, 88 were removed for the production of the psychosocial clusters and 74 for that of the IEQ clusters, due to not having completed the key variables for the production of the cluster models. Furthermore, because the questionnaire allowed skipping questions, certain questions remained unanswered, however, respondents who skipped more than 80% of the questionnaire were fully excluded, which was the case with 31 respondents (Table 1).

Table A1 (in Appendix A) shows characteristics of the study respondents per participating organization. About one-third of the workers were women (sex ratio female/male: 0.56). The mean (s.d.) age of the respondents for all organizations was 42 (12) years. Concerning their lifestyle, 36% reported to be current smokers and 83% reported consuming alcohol. Most declared to do some form of physical activity (85%), and on average 78% of the respondents reported to work at home

Table 1

Total number of office workers invited and respondents per participating organization.

Organisation	Type of organization	Invited	Respondents	Response rate %
1	Consultancy	209	56	27
2	Faculty of university	495	109	22
3	Branche organisation	25	20	80
4	Contractor	300	101	34
5	Consultancy	40	8	20
6	Faculty of university	300	72	24
7	Knowledge centre	30	19	63
8	Consultancy	60	33	55
9	Architect	200	51	26
10	Consultancy	70	33	47
Total		1729	502	29

during the lockdown.

Fig. 1 shows the mood of the respondents at the time they were completing the questionnaire. 28.5% of the respondents reported being tensed, irritated, sad or bored.

3.2. Health status

To establish their health status, the office workers were asked whether they had suffered from a number of conditions in the last year (Fig. 2). 16% of the respondents reported to have suffered from COVID-19 (n = 348). The most-reported diseases were hay fever (31%), rhinitis (28%), eczema (18%), and anxiety (17%).

3.3. IEQ perceptions and preferences

3.3.1. Perceived IEQ

Fig. 3 presents the mean and standard deviation of perceived IEQ-aspects at the most used workplace (whether at home or the office). In general, workers reported feeling comfortable with the temperature (5.2 ± 1.5), air quality (5.3 ± 1.4), natural light (5.4 ± 1.5), light overall (6.4 ± 2.7), sound overall (5.2 ± 1.3), and comfort overall (5.4 ± 1.2). Air was found to be fresh (5.6 ± 1.3) and odourless (5.3 ± 1.2).

3.3.2. Preferences IEQ

Figs. 4 and 5 present the mean and standard deviation of importance rating for IEQ aspects and IEQ items, respectively, on a scale from 1 (not important at all) to 10 (extremely important).

3.3.3. Correlations between perceived IEQ and preferences

To establish whether the perception of IEQ should be included or not in the clustering of IEQ preferences, correlations between IEQ perception and IEQ preferences for different aspects of IEQ were performed. From the results (see Table 2), it can be concluded that perception cannot be included in the clustering due to too many relevant correlations with a Phi >0.3. Multicollinearity is therefore avoided.

3.4. Psychosocial comfort and preferences

3.4.1. Perceived psycho-social comfort

The perceived comfort the psychosocial aspects privacy, layout, decoration, cleanliness, and view to outside reported, is presented in Fig. 6.

3.4.2. Psycho-social preferences

Preferences for psycho-social aspects are presented in Fig. 7.

3.4.3. Correlations between perceived psycho-social comfort and preferences

To establish whether the perception of psychosocial comfort should be included or not in the clustering of psychosocial preferences, correlations between psychosocial comfort perception and preferences for different aspects were performed. From the results (see Table 2), it can be concluded that comfort perception cannot be included in the clustering due to too many relevant correlations with a Phi >0.3. Multicollinearity is therefore avoided.

3.5. Clustering of workers

3.5.1. Most used workspace

To check whether all respondents, with the most used workplace at home or the office, could be merged to perform clustering of the office workers, correlations were performed for both the IEQ and psychosocial preferences between those who worked mostly at home and those who worked mostly at the office. Table 3 presents the p-value and the Phi-values. The results suggest that as far as IEQ preferences are concerned, the only statistically significant differences between working from home and at the office are found in the preference for the presence of windows (p = 0.050; φ = 0.202) and the preference for artificial light (p = 0.017; φ = 0.216). As for the psychosocial preferences, statistically significant differences were found in the presence and company of others (p < 0.000; φ = 0.316), for the size of the room (p < 0.000; φ = 0.305), and for controlling the place (p = 0.023; φ = 0.212). However, the effect size for the IEQ variables has a moderate strength (0.2 < φ < 0.3), suggesting that the difference between two groups' means is

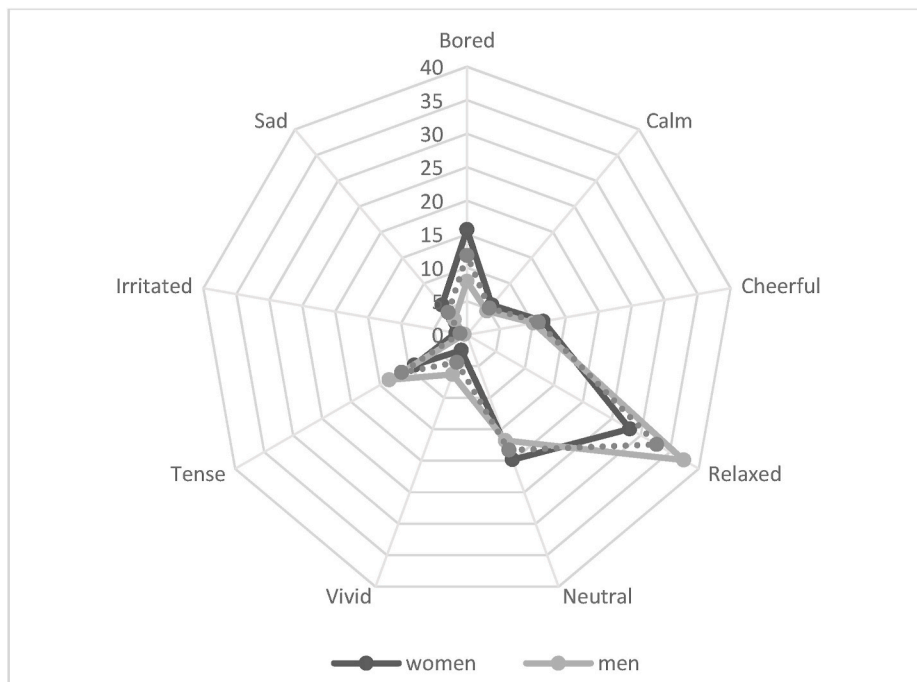


Fig. 1. Mood of the respondents while taking the survey (%).

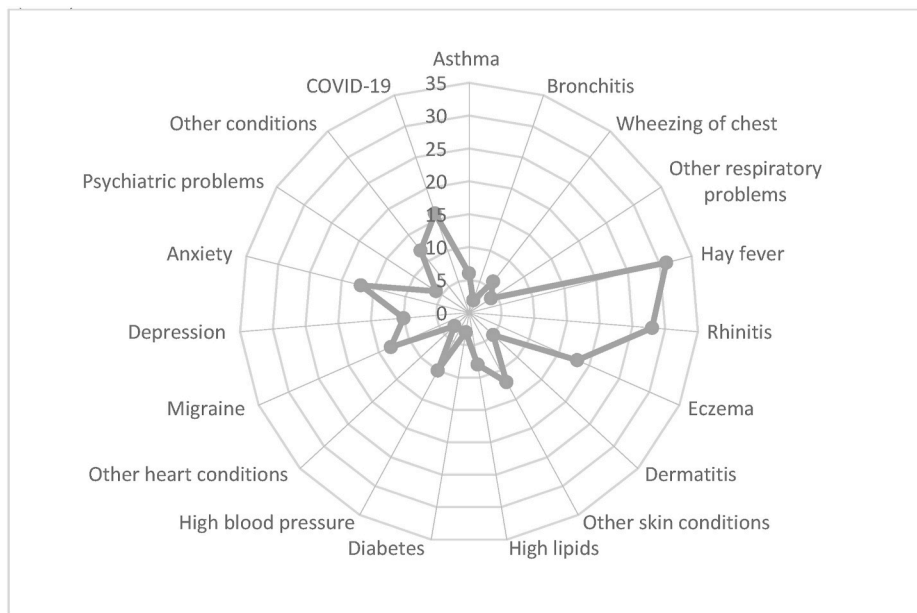


Fig. 2. Prevalence of diseases in the last 12 months (%).

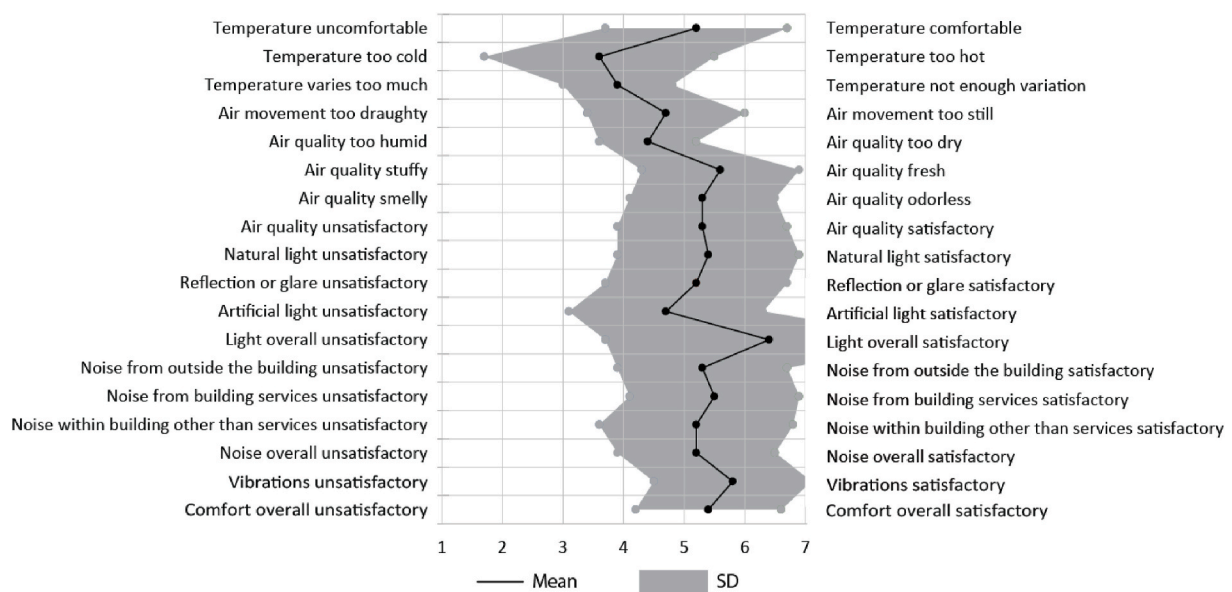


Fig. 3. IEQ perception in the past month at their most-used workplace (at home or the office) (on a scale of 1–7).

negligible, even if it is statistically significant. The effect size is also moderate for ‘control of place’ under the psychosocial comfort preferences. However, the presence of others and the size of the room do present a strong relationship due to their effect size ($\varphi > 0.3$). As a result, the cluster models for both types of comfort were produced by considering both working from home workers and office workers.

3.5.2. Reduction of variables with PCA

As the number of original variables was too large to perform the TwoStep cluster analysis, PCA was conducted with the variables of IEQ perceptions and those of psychosocial preferences. Four components result from IEQ preferences and three from psychosocial preferences (Table 4).

Namely, for IEQ preferences, the original ten variables were reduced to four components: “sounds and smells” (sounds from the inside, sounds from the outside, and smells); “outdoor connection” (presence of

windows, natural light); “localized thermal comfort” (temperature of feet, temperature of chair); and “general comfort from building systems” (ventilation, general temperature, artificial lighting).

For the psychosocial comfort preferences, the nine original variables were reduced to three components: “ability to control the environment” (adapt the place, identifying with the place, control of privacy); “ergonomic comfort” (chair type, desk and monitor size, cleanliness); and “adequacy of size and spaces” (enough space, non-crowdedness, storage space).

3.5.3. Two steps cluster analysis

Clusters were made with SPSS TwoStep cluster analysis, based on the IEQ preferences of the respondents and their psychosocial comfort preferences. Two sets of clusters were produced, one for the IEQ preferences and one for the psychosocial preferences; to produce two reliable models based on a smaller number of related variables, rather than

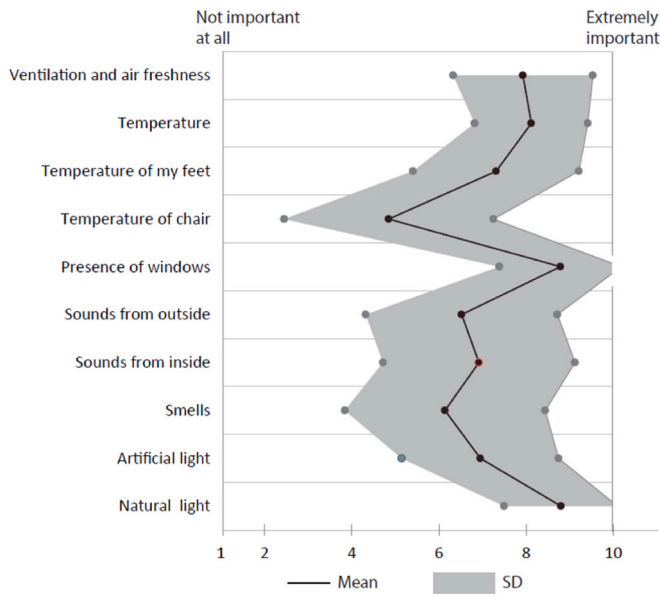


Fig. 4. IEQ Preferences (1: not important at all; 10: extremely important).

one weaker model of mixed and more variables.

The clustering analysis for IEQ preferences yielded four distinct clusters, while the analysis for psychosocial comfort preferences yielded six clusters. The two models were successfully validated with the four-step methodology (silhouette of coherence 0.2, Chi² tests for the variables, variable predictor coefficient above 0.02).

3.5.4. IEQ preferences profiles

Table B1 in Appendix B presents the means (SD) of the IEQ variables composing the IEQ clusters. The descriptives of the four IEQ clusters are presented in Table B2 (Appendix B).

3.5.4.1. EPC1. Environmental Preference Cluster 1 (EPC1) tends to have a sensitivity to air quality factors, specifically, it scores highest on

‘too still’ (4.7); ‘too humid’ (4.3), ‘air quality unsatisfactory’ (5.2), yet, they also have the highest for air ‘too fresh’ (4.7). Light factors are also of importance for EPC1, namely, they score the highest dissatisfaction of all profiles on ‘glare’ and ‘light overall’ (both 5.1). finally, they rate the most ‘too cold’ perception of all profiles with 3.5. EPC1 has a high control over light items in their workspace: lighting and shading (5.6 and 5.7), which is coherent with their satisfaction of IEQ results. While having a low control over noise (3.5), and medium control over temperature and ventilation (5.3 and 5.2).

EPC1 gives the highest importance of all profiles to several aspects to work better in the workspace. Namely, having a desk lamp and being able to control room shading (6.7 and 7.9), heating of chair, of the desk, and room temperature control (3.5; 3.3; 8.5), as well as room ventilation (7.9), plants (7.0), and having headphones (6.6).

As far as health is concerned, they are the cluster with the highest prevalence of diseases and conditions, especially related to skin or psychological problems. Namely, they have the highest prevalence of all clusters for dermatitis and other skin conditions (21%), for depression, anxiety, psychiatric problems, and other conditions (14%, 24%, 8%, 19%), and rhinitis (33%). Yet, for asthma (3%), bronchitis (0%), and other respiratory conditions (3%) they have the lowest number of sufferers, as well as for high lipids in blood and diabetes (3% and 2%).

In terms of satisfaction, EPC1 doesn’t present extreme scores compared to the other profiles, however, it is mainly satisfied with their privacy, cleanliness, and view (5.8; 5.6; and 5.6), while also satisfied to a lower degree with their decoration and layout (5.4).

3.5.4.2. EPC2. EPC2 has the highest sensitivity to thermal comfort aspects, rating highest satisfaction to general temperature (5.2), highest score with ‘too hot’ as well as with temperature varies too little (3.6; 4.0). they are also the most unsatisfied cluster in terms of air quality, having too smelly and general air quality dissatisfaction as the lowest of all groups both with a mean score of 5.2. They are also the most unsatisfied cluster with natural light and glare (both 5.1), as well as with noises from inside (5.0) and from the building services (5.3). Being the most dissatisfied cluster goes in line with the fact that this is the cluster with the least control; in particular, they score the lowest levels of control for temperature (5.2); ventilation (4.8); and lighting (5.0). EPC2

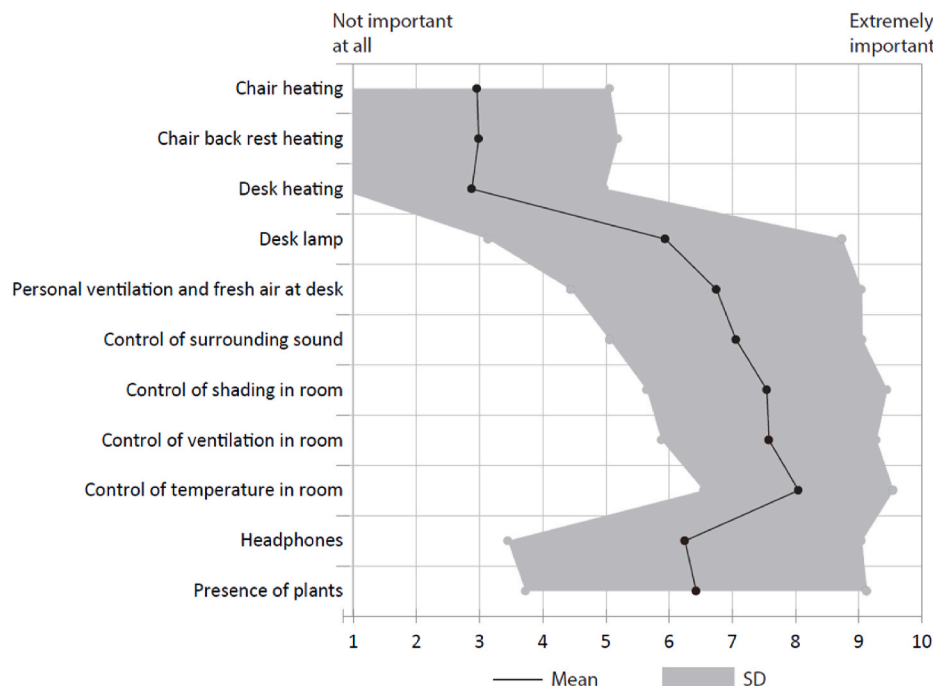


Fig. 5. Items to work better importance: (1: not important at all; 10: extremely important).

Table 2
Correlations between: perceived IEQ and preferences for IEQ aspects, and, between satisfaction and psychosocial comfort preferences.

IEQ perception	IEQ preferences	p-value	Phi
Temperature overall	Temperature of space	0.000	0.575
Temperature overall	Temperature feet	0.459	0.362
	Temperature chair	0.283	0.379
Too hot or too cold	Temperature of space	0.013	0.406
Varies too much or too little		0.002	0.447
Too hot vs too cold	Temperature feet	0.661	0.331
Varies too much vs too little		0.001	0.479
Too hot vs too cold	Temperature of chair	0.006	0.418
Varies too much vs too little		0.046	0.421
Too drafty or too still	Ventilation	0.000	0.559
Too humid or too dry		0.949	0.304
Stuffy or fresh		0.372	0.371
Smelly or odourless	Smells	0.222	0.357
Natural light	Natural light	0.000	0.449
Reflection and glare from sky	Presence of windows	0.854	0.303
Artificial light	Artificial light	0.537	0.356
Overall light	Natural light	0.453	0.320
	Artificial light	0.653	0.345
Noise from outside	Sounds from outside	0.060	0.415
Noise from systems	Sounds from inside	0.131	0.399
Noise from people		0.165	0.394
Satisfaction	Psychosocial preferences	p-value	Phi
Privacy	Storage	0.001	0.476
	Presence of others	0.141	0.400
	Control of place	0.630	0.350
	Size of room	0.275	0.383
	Privacy	0.081	0.411
Layout	Storage	0.080	0.413
	Amenities	0.003	0.460
	Presence of others	0.003	0.463
	Size of room	0.222	0.389
	Privacy	0.045	0.422
Décor	Control of place	0.178	0.394
	Amenities	0.038	0.425
	Chair type	0.685	0.345
	Size of room	0.003	0.464
Cleanliness	Storage	0.197	0.394
	Cleanliness	0.085	0.390
	Amenities	0.003	0.462
	Presence of others	0.009	0.447
	Size of room	0.000	0.489
	Control of place	0.288	0.381
View	Size	0.622	0.351
	Control of place	0.928	0.311

Note: Phi value for the strength of association is strong when >0.3.

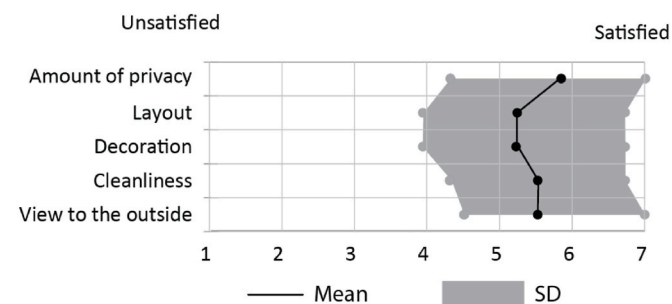


Fig. 6. Satisfaction with workspace psychosocial items reported by the respondents.

gives also the highest importance to thermal items to work better such as desk, chair, and backrest heating (3.3; 3.4; 3.4), however, they give the lowest to control general temperature (7.6), and of the control of both general ventilation and personal ventilation (7.0 and 6.5).

As for health, this is the second healthiest group, showing the lowest prevalence of wheezing (4%), hay fever (26%), dermatitis (2%),

migraine and depression (6%), and anxiety (7%). However, it is the group suffering from high lipids in the blood, high blood pressure, and diabetes (11%; 14%, and 4%).

The group also scored the lowest rating in terms of satisfaction, particularly with privacy, cleanliness, and view (5.5; 5.3; 5.2).

3.5.4.3. EPC3. This cluster has the most extreme ratings for two thermal variables: temperature varies too little and air too draughty (3.8 and 4.5), it is also the second most bothered by a smelly environment (5.2), and is the most dissatisfied with the artificial light (4.6), noise from outside (4.7), and noise overall (4.9). As for the levels of control, EPC3 shows the highest levels for both temperature and ventilation (5.6 and 5.4), but the lowest for shading and noise (5.3 and 3.4).

For aspects that would help them to work better, this cluster gives the lowest importance to localized heat (chair, backrest, and desk heating) with 1.9; 1.9; and 1.8 respectively. However, it prioritized personal ventilation the highest and control of sound (7.0 and 7.4).

EPC3 is the unhealthiest cluster, having the highest prevalence in asthma (8%), wheezing in the chest (6%), heart conditions (4%), and highest prevalence having suffered COVID-19 with 27%. However, the cluster shows the lowest prevalence for rhinitis and eczema (24% and 14%).

Finally, in terms of satisfaction, the cluster has the highest one for two items: layout (5.2) and decoration (5.1).

3.5.4.4. EPC4. This cluster is sensitive to sound, visual, and air quality stimuli, and also, to a lesser degree to thermal ones. It rates the most extreme score for ‘too cold’ temperature (3.6). For air quality, it rates the highest satisfaction for freshness, odourless, and general satisfaction for air quality (4.7; 5.5; 5.5). For the light variables, natural light, artificial light, and overall light, this cluster is the most satisfied of all with the highest rating 5.9, 4.9 and 5.6 respectively. The perception results go in line with the fact that this cluster has the highest control of all clusters for most items, namely: ventilation (5.4), shading (6.0), lighting (5.7), and noise (3.8). However, it is the cluster with the lowest given importance particularly for desk lamp (4.9), for the need of control of sound (5.8), need of control of shading (7.1), for headphones (5.5), and plants (5.8).

EPC4 is the healthiest cluster with the lowest prevalence of bronchitis (0%), skin conditions (6%), blood pressure and other heart conditions (6% and 0%), and psychiatric problems (2%). However, it shows the highest prevalence of hay fever (38%) and eczema (22%).

The cluster is also the highest satisfied for the items of privacy (6.1), layout (5.6), decoration (5.6), and view (5.8).

3.5.5. Psycho-social profiles

Table C1 in Appendix C presents the means (SD) of the psychosocial variable composing the psycho-social clusters. The descriptives of the six psychosocial clusters are presented in Table C2 (Appendix C).

3.5.5.1. Cluster PC1. As far as IEQ perception in the most used workplace is concerned, PC1 is the most dissatisfied group in terms of the sound variables, specifically with noise from inside, noise overall, and vibrations; however, the profile has the highest satisfied average for ‘temperature in general’, and for ‘temperature too hot’; as well as for the ‘overall light’ variable. Therefore, in terms of IEQ perception, PC1 seems to be particularly sensitive to temperature and sound.

The interaction with the workspace variables, meant to assess the control of the respondents over certain items, goes in line with the results of the IEQ perception, namely that this group is sensitive to temperature and noise, and hence rates its control over the temperature as the highest (5.2 out of 7); while rating its control over the noise as the lowest (3.9). As for items needed to work better in the workplace, PC1 rates with the highest heating in the backrest of the chair (3.5) and desk heating (3.4). However, the sound-related items (control of sound and

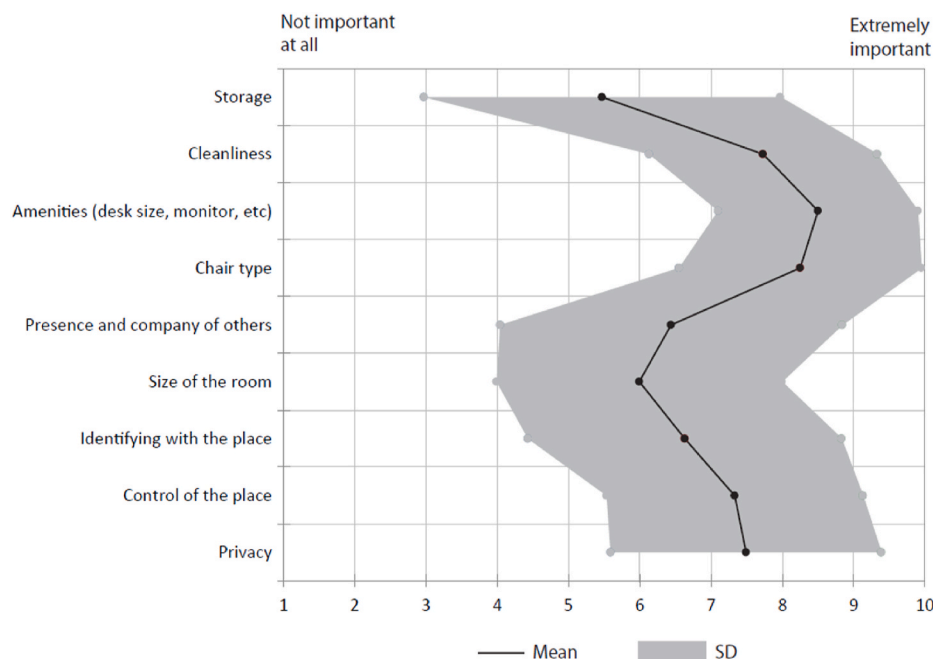


Fig. 7. Psycho-social comfort preferences reported by the respondents.

Table 3

Chi² tests of correlation between IEQ and psychosocial preferences with main workspace (home or office).

IEQ preferences	p-value	Phi	Psychosocial comfort preferences	p-value	Phi
Ventilation and air freshness	0.789	0.113	Storage	0.061	0.196
Temperature	0.315	0.155	Cleanliness	0.312	0.148
Temperature of my feet	0.052	0.197	Amenities (desk size, monitor, etc.)	0.922	0.095
Temperature of chair	0.068	0.192	Chair type	0.407	0.148
Presence of windows	0.040	0.202	Presence and company of others	0.000	0.316
Sounds from outside	0.239	0.163	Size of the room	0.000	0.305
Sounds from inside	0.164	0.173	identifying with the place	0.529	0.138
Smells	0.277	0.159	control the place	0.023	0.212
Artificial light	0.017	0.216	Privacy	0.366	0.151
Natural light	0.067	0.184			

use of headphones) were rated with average importance (5.7 and 5.9).

In terms of health, PC1 has the highest sufferers of bronchitis (7.1%) and the highest prevalence of heart-related conditions with almost 20% suffering from one. However, it is the profile with the lowest rate of hay fever and eczema with only 25% and 12% of sufferers, respectively.

PC1 is the most unsatisfied cluster in terms of both privacy at the workspace and the layout of the workspace (5.4 and 5.1).

3.5.5.2. Cluster PC2. PC2 is the most unsatisfied cluster in terms of temperature items (general temperature, too cold temperature, temperature varies too much). However, the cluster is the most satisfied with light-related variables, particularly glare and artificial light (5.7 and 5.0). With the factor noise, PC2 is the most unsatisfied with noise coming from outside and noise overall (4.3; 5.0), yet they have the highest satisfaction for noise from the building services with a 5.9 overall rating. As for air quality variables, the cluster shows the highest satisfaction of all clusters with the most odourless and air quality in general, both with 5.4 ratings. Conversely, it is the profile with the

highest humidity dissatisfaction. Therefore, light and temperature variables are of concern to this cluster, and to a degree of air quality.

Such results are coherent with those of control over elements, in which PC2 doesn't not present extreme ratings but finds a high degree of control over lighting, shading, and ventilation (5.8; 5.7; 5.3).

For aspects to work better, PC2 has the lowest ratings of all, reflecting that they don't find the following items important at all to work better: all of the heating variables (chair, backrest, and desk), as well as giving the lowest ratings for personal ventilation, control of sound, control of shading, and presence of plants.

As far as diseases are concerned, PC2 scores lowest in wheezing, respiratory problems, dermatitis, and diabetes, all with 0%, and with migraine (7.4%), depression 3.7%), anxiety (7.4%), and other conditions in general (3.7%); making it the healthiest cluster of all.

Finally, it is the most satisfied cluster of all, having the top ratings for privacy (6.4), cleanliness (5.7), and view to the outside (5.9).

3.5.5.3. Cluster PC3. Regarding IEQ perception in the last month, PC3 does not present extreme ratings compared to other profiles. They only score as most satisfied with natural lighting, with a 5.3 rating, and most unsatisfied with noises from building services, also with 5.3.

Compared to other clusters, PC3 has average control over different factors in the workspace. Their highest rating was given to control over shading and lighting (5.6 and 5.4) reflecting their result with light satisfaction, and their lowest control lies with noise and ventilation (3.5 and 5.1); also in line with their dissatisfaction with noise from services.

In terms of aspects to work better, this profile has the highest score for every single item.

PC3 has average health, however, the profile represents the highest prevalence of both anxiety and depression (13%; 22%).

The profile is the most satisfied with its layout (5.1) and decoration (5.0).

3.5.5.4. Cluster PC4. PC4 rated their perception of air quality aspects in extreme ways having the highest ratings for drafty air, dryness, air freshness, and general air quality as satisfactory; while also having a rating that tends most towards 'smelliest'. Therefore, the cluster seems to be sensitive to air quality. Furthermore, they have the highest dissatisfaction with natural light, but the highest satisfaction of all

Table 4
Component Matrix of IEQ preferences and of Psychosocial comfort preferences.

IEQ preferences					
PCA Name	Original variable	Component 1	Component 2	Component 3	Component 4
Sounds and smell	Sounds from inside	0.835			
	Sounds from outside	0.785			
	Smells	0.706			
Outdoor connection	Natural light		0.883		
	Presence of windows		0.811		
Localized thermal comfort	Temperature of the chair			0.863	
	Temperature of my feet			0.686	
General comfort from building systems	Ventilation				0.691
	General temperature				0.601
	Artificial light				0.503
Psychosocial preferences					
PCA Name	Original variable	Component 1	Component 2	Component 3	Component 4
Ability to control the environment	Adapt the place	0.751			
	Control of privacy	0.75			
	Identifying with the place	0.659			
Ergonomic comfort	Chair type		0.867		
	Amenities (desk size, monitor size, etc.)		0.851		
	Cleanliness		0.388		
Adequacy of spaces	Non-crowdedness				0.785
	Enough space of the room				0.727
	Storage space				0.447

clusters with lighting in general.

PC4 gave the highest control to shading, lighting and temperature, and the lowest control ratings to ventilation and noise. In terms of aspects needed to work better, PC4 rates the lowest scores for control of room ventilation and control of room temperature (7.0 and 7.6). control of shading, control of surrounding sounds, and control of desk ventilation are rated highly as important aspects to work better, with scores ranging from 7.0; 6.7; and 6.5 respectively. Conversely, the least important aspects for PC4 are all three heat-related aspects (chair, backrest, and desk heating) all with a 2.6 score.

In terms of health, they are the least healthy, with the highest prevalence of asthma (9%), wheezing (10%), respiratory problems (6%), and psychiatric problems (10%).

In terms of satisfaction with workspace items, they show the highest satisfaction with cleanliness; while the rest of the items have average ratings compared to the other profiles; however, their highest satisfaction is rated with the privacy and view (5.8 and 5.5), while their own lowest rating is decoration, layout, and cleanliness itself, all with 5.3 ratings.

3.5.5.5. Cluster PC5. Generally, PC5 is the cluster in which respondents express most dissatisfaction with IEQ perception in their workplace. Three of the five air quality items are rated with extreme scores: too humid (4.2); too smelly (5.2) and general air quality unsatisfactory (5.0). a similar trend occurs with the light factors for which the score highest dissatisfaction with general natural light, artificial light, and light overall (5.2; 4.5; and 5.1).

In terms of control over workspace components, they rated as lowest of all them, making them the profile with the least control. Specifically, noise and ventilation were rated lowest (3.2; 4.5) followed by lighting, shading, and temperature (5.1; 5.2; 5.2). As for aspects to work better, in relation to other profiles, PC5 has average scores. It rates as most important aspects the following control of room temperature, control room ventilation, control of shading, and control of surrounding sound, with 8.0; 7.7; 7.2; and 6.6 respectively. On the other end, it rates all of the local heating elements as least important amongst all items; while having headphones is rated as the least important out of all the clusters.

PC5 is quite an unhealthy cluster, having the highest prevalence for hay fever (53%), for eczema, dermatitis, and other skin conditions (29; 8; 24%); as well as highest prevalence for those who contracted COVID-

19 with 23%. However, they do have the lowest prevalence for asthma (3%), rhinitis (18%); high blood pressure and other heart conditions (5.3 and 0%); and for psychiatric problems (3%).

PC5 is the most satisfied profile for the decoration of their workplace and the cleanliness (both 5.7). additionally, there are most satisfied with their privacy (6.0); and the items with which they are least satisfied are layout and view, both with 5.4.

3.5.5.6. Cluster PC6. PC6 seems to have sensitivity to factors related to air quality and noise. Specifically, they score highest on 'too still' (4.7) and 'odourless' (5.4), and contradictorily, on 'too stuffy' (4.5). For noise variables, they have the highest satisfaction of all profiles in terms of 'noise from inside' (5.4) and vibrations (6.0). Finally, they are the most unsatisfied cluster, along with PC5, with artificial light (4.5).

PC6 is the profile scoring highest of all for control over workspace items, specifically for lighting (5.9), shading (5.8), temperature (5.6), and ventilation (5.5). as far as the items to work better are concerned, PC6 has an average score compared to the rest of the profiles. They regard a desk lamp and personal desk ventilation with the highest importance (6.2 and 6.8) of all profiles.

As far as health is concerned, they score the lowest for certain conditions such as bronchitis (0%), skin conditions (3%), high lipids (7%), and COVID-19 (14%); while scoring the highest prevalence of all profiles on rhinitis (32%), diabetes (5%), migraine (24%), and other conditions (15%).

As for satisfaction PC6 is the least satisfied with their view to the outside (5.3) but they are the most satisfied with the layout (5.7).

4. Discussion

4.1. Comparison to other workplace studies in the Netherlands

Previous workplace studies in the Netherlands comprise of the 1014 office workers studied in the Netherlands as part of the European OFFICAIR project [39] and the study performed by Eijkelenboom et al. [41] among 566 workers at outpatient areas of hospitals in the Netherlands. In Table 5 a comparison is presented of demographics, personal characteristics, and health status among these studies and this study.

With regards to demographics, the respondents in this study are

Table 5
Comparison of demographics, personal characteristics, and health status among three workplace studies in the Netherlands.

	OFFICAIR NL	Hospitals	MyWorkplace
sample	1014	566	471
gender: % female	49.6	91.0	35
age: mean (SD)	43 (11)	50 (12)	42 (12)
education			
- Master, PhD, specialization	36	15	45
- University, college, equiv.	32	21	31
- Professional	14	53	11
- Secondary school	17	11	6
- Primary school or less	1	0	7
smoking current (%)	14	4	36
alcohol yes (%)	81	69	83
physical activity	-	27	85
mood: negative	-	15.0	23.5
medical history			
migraine (%)	8	10	13
asthma (%)	9	7	6
eczema (%)	11	7	18
rhinitis (%)	-	-	28
hay fever (%)	-	-	31
allergy (%)	23	19	-
high lipids in blood (%)	6	4	8
high blood pressure (%)	11	13	10
diabetes (%)	3	2	3
depression (%)	4	2	10
anxiety (%)	2	2	17
heart conditions (%)	3	2	3
psychiatric problems (%)	3	1	6

similar to the OFFICAIR study, except for gender: 35% in this study, nearly 50% in OFFICAIR. In the hospital study, this percentage was even higher (91%), while the mean age was slightly higher than in the office studies, and the education level differed considerably.

Comparing the medical history from the respondents in this study with the office workers who responded in the OFFICAIR project in the Netherlands, an increase in the percentage of workers having had eczema in the past year, from 11% to 18%; and an increase in percentage having suffered from migraine (from 8% to 13%), depression (from 4% to 10%), anxiety (from 2% to 17%) and psychiatric problems (from 3% to 6%).

What is also interesting, is that the percentage of respondents currently smoking has increased from 14 to 36%. Of course, it should be noted that the respondents from this study are not the same as the respondents from the OFFICAIR study, so an actual comparison is not possible. However, comparing the medical history of the respondents in this study with the hospital staff of the outpatient areas shows similar results, indicating an effect of working at home.

As far as anxiety and depression are concerned, in a study in the UK during the lockdown, a survey administered to 2000 adults working from home, reported that anxiety and depression amongst the sample was 22% and 24% respectively when the regular rates would be 5% and 7% [42]. The increase in depression and anxiety was partly explained by unstable finances, poor social connections, household conflicts, while also females and younger age respondents were more vulnerable.

Although not previously asked in the office worker studies, in this study the respondents reported high rates of rhinitis (28%) and hay fever (31%). Although hay fever is a form of allergic rhinitis, allergic rhinitis is caused by our immune system reacting to allergens your breath in, while hay fever, we respond to pollens, but it can be easily confused with (allergic) rhinitis. Bousquet et al. [43] estimated a range of 17–28.5% of the population in Europe have rhinitis. In a previous study with students in the Netherlands [44], 33% reported having suffered from rhinitis in the past 12 months. In that study, the risk of having rhinitis was found to be associated with genetics (parents having rhinitis), biological pollutants (presence of pets) and chemical pollutants (presence of MDF from less than one-year-old furniture) at home, ventilation (opening windows

in bedroom more than once a week), and with personal factors, working out (physical activity). It could be that working at home, increased the risk for having rhinitis. Unfortunately, no comparison could be made.

4.2. Profiling

In this study that was conducted during the 2020 lockdown in the Netherlands, around 20% of people were working more than half of their working hours in the regular office. However, because of the results of the Chi² tests (Table 2), it was concluded that it was appropriate to cluster all employees, regardless of their main workspace during the lockdown.

Four IEQ preference clusters were found in this study, based on 4 factors. Comparing the clusters rating of IEQ perception shows that they only differ in their rating of natural light ($p = 0.007$) and noise coming from outside ($p = 0.040$). The clusters also show differences in terms of control of lighting workspace ($p = 0.033$). However, the largest statistically significant differences between the IEQ preference clusters, besides those of the preferences themselves, are workspace items that are important to work better. These clusters also differed in terms of the workspace location during the lockdown ($p = 0.039$).

Six psychosocial preference clusters were found, based on three factors. These clusters differ in terms of the lockdown workspace ($p < 0.000$). There were also statistically significant differences in the importance of aspects to work better, particularly in the control of items, such as control of sounds and room temperature (both $p < 0.000$).

The fact that both models showed statistically significant differences for the locations, may indicate that both psychosocial preferences and IEQ preferences are situation-dependent. These findings go in line with those found by Ref. [41] in which the authors suggest that preferences are situation-related. Several studies have also suggested that some types of preferences are indeed situation-related, as they can be formed out of conscious reasoning, and can be changed as the situation changes [45–47].

Previous clustering studies in which a similar clustering method and clustering variables were used show certain similarities. One study [39] found three clusters based on 16 variables assessing the IEQ perception of workers. This study found large differences in comfort affected by gender. In this study, although no such gender differences were found, there are statistically significant differences in gender for the IEQ preferences clusters ($p < 0.000$) as well for the psychosocial comfort preferences clusters, albeit less strong ($p = 0.045$). Such results suggest that IEQ preferences vary more between gender, as suggested by the literature [48].

Another similar study [41] aimed at clustering hospital staff members based not only on variables about their perception of IEQ variables but also on psychosocial comfort variables. The results found six IEQ-related clusters (based on 9 variables) and the three psychosocial clusters (based on 5 variables). The discrepancies between the number of clusters found in these studies can be explained by the fact that study assessed hospital staff, who do not tend to have a fixed workspace, because a different way of response was required by participants for the social comfort preference variables, which they were asked to rank in a top-three scale, and because around 91% of respondents in that study were women, which may show that gender differences in terms of preference exist.

In the study amongst hospital staff, clustering was performed by using in the same model both preferences and perceived variables, as significant correlations were weak, while also showing negligible effect sizes, and multi-collinearity was limited [41].

4.3. Strengths and limitations

Although this study sample was not representative of office workers in the Netherlands, it was a first attempt to investigate preferences for IEQ and psychosocial comfort at the workplace, whether at home or the

office, during the COVID-19 pandemic.

One of the limitations of this study is that during the COVID-19 pandemic, many people worked from home, and therefore no inspection was made of their workplace, but also no health effects specifically related to the office environment (their office building) could be identified.

The response rate of the questionnaire was 29%, and only 27% (counting the 80% completed questionnaires). The reason for this can be the fact that the study was only based on a self-reported questionnaire, gathered through email and completed digitally [49].

5. Conclusions

In conclusion, profiles for both IEQ and psychosocial preferences were determined. For IEQ four clusters were identified and for psychosocial preferences six clusters. The results indicate that the IEQ preferences clusters group the office workers into variables about sounds and smells, the presence of windows, localized temperature, and building systems. These clusters also showed differences in the perception of natural light and overall light; in their control levels of shading and lighting, and the importance of several aspects to work better. As for the psychosocial preferences, clusters differed on variables about the personalization of the place, the ergonomics and hygiene, and the size of the space. The psychosocial preferences cluster also had significant differences in terms of the importance of different aspects to work better.

Furthermore, the comparison of the current results with other clustering studies proposes that preferences are situation-related, therefore, can be changed from situation to situation, but also that gender may play an important role in the IEQ and psychosocial preferences.

Appendix A

Table A1

Demographics and personal characteristics.

Office n ^a (%)	1	2	3	4	5	6	7	8	9	10	Total
gender											
Male	39 (72)	53 (54)	12 (60)	79 (81)	5 (71)	29 (41)	12 (71)	25 (81)	17 (39)	27 (82)	298 (63)
Female	14 (26)	43 (44)	7 (35)	15 (16)	2 (29)	41 (58)	5 (29)	6 (19)	27 (61)	5 (15)	166 (35)
Prefer not to answer	1 (2)	2 (2)	0	3 (3)	0	1 (1)	0	0	0	0	7 (2)
Age											
Mean (SD)	41.4 (13)	42.9 (12)	40.2 (11)	45.3 (12)	41.1 (10)	40.6 (13)	43.2 (11)	38.7 (13)	35.4 (8)	45.5 (12)	42 (12)
Min	22	21	25	21	31	29	20	22	23	23	20
Max	64	68	59	65	42	38	67	66	57	66	68
Level of education											
Master, PHD, Specialization	22 (39)	84 (77)	6 (30)	6 (6)	3 (38)	51 (71)	8 (42)	2 (6)	34 (66)	8 (24)	224 (45)
University	23 (41)	5 (5)	13 (65)	45 (45)	4 (50)	10 (14)	5 (26)	23 (70)	10 (20)	16 (49)	154 (31)
Professional	6 (11)	8 (7)	0	25 (25)	0	7 (10)	3 (16)	4 (12)	0	4 (12)	57 (11)
Secondary School	3 (5)	10 (9)	1 (5)	3 (3)	1 (13)	1 (1)	2 (11)	2 (6)	7 (14)	1 (3)	31 (6)
Primary school	2 (4)	2 (2)	0	21 (20)	0	3 (4)	1 (5)	2 (6)	0	4 (12)	35 (7)
None	0	0	0	1 (1)	0	0	0	0	0	0	1 (0)
Smoking	9 (16)	39 (36)	9 (45)	45 (45)	1 (13)	24 (33)	3 (16)	8 (24)	23 (49)	15 (46)	178 (36)
Alcohol	45 (80)	84 (77)	18 (90)	93 (92)	6 (75)	63 (88)	16 (84)	24 (73)	40 (78)	27 (82)	416 (83)
Physical activity Yes	48 (89)	89 (91)	17 (90)	73 (75)	3 (43)	63 (91)	16 (94)	24 (77)	38 (86)	25 (81)	396 (85)
Lockdown workspace											
Home	48 (98)	83 (93)	18 (100)	46 (51)	4 (57)	54 (83)	12 (80)	21 (70)	35 (81)	22 (73)	343 (78)
Office	1 (2)	6 (7)	0 (0)	45 (49)	3 (43)	11 (17)	3 (20)	9 (30)	8 (19)	8 (27)	94 (22)
Control of office; 1: none vs 7: high mean and SD											
temperature	5.5	5.8	5.3	4.9	5.7	5.7	5.6	4.8	5.4	5.1	5.4
	1.3	1.3	1.6	2.0	1.5	1.4	1.3	1.9	1.8	1.8	1.7
Ventilation	5.2	5.7	5.3	4.9	5.7	5.4	5.0	4.2	5.4	4.3	5.2
	1.7	1.5	1.4	2.0	1.5	1.8	2.4	1.9	2.0	2.2	1.9
Shading	5.8	5.6	5.6	5.6	5.3	5.8	4.9	4.8	5.4	5.4	5.5
	1.4	1.7	1.5	1.6	1.8	1.7	2.0	2.4	1.7	1.8	1.7
Lighting	6.0	5.9	5.8	5.0	5.0	5.8	4.8	4.8	5.0	5.1	5.4
	1.0	1.4	1.4	2.1	1.7	1.3	2.1	2.1	1.7	1.9	1.7
Noise	3.9	3.6	3.7	4.0	3.3	3.5	3.5	3.2	3.2	3.4	3.6
	1.7	1.6	1.3	1.6	1.3	1.8	1.6	1.5	1.8	1.4	1.6

(continued on next page)

Finally, these results suggest that regardless of the cluster, working from home format may be of concern during lockdown situations, as the prevalence of both anxiety and depression and migraine and rhinitis, were higher than found in previous studies of office workers.

CRedit authorship contribution statement

Marco A. Ortiz: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Philomena M. Bluysen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

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

The following persons from the participating organizations are thanked for their help in organizing the office workers to complete the questionnaire: Marisa Cortright (UNStudio), Marije te Kulve (BBA-DGMR), Remco van Woensel (Heijmans), Jacques Mol (Valstar-Simonis), Ruud van Lewe (Techniplan), Marco Hofman (ISSO), Jan Kadijk (DGBC), Linsey Merling Meijer (IGG), Amber Leeuwenburgh (faculty of Architecture and the Built Environment TU Delft), Hans Suijkerbuijk (faculty of Industrial Design TU Delft).

Table A1 (continued)

Office n ^a (%)	1	2	3	4	5	6	7	8	9	10	Total
Satisfaction with workspace unsatisfied vs satisfied: mean and SD											
privacy	6.0 1.4	6.0 1.4	6.1 0.9	5.7 1.3	6.0 1.4	6.0	5.9	5.3	4.9	5.8	5.8
layout	5.7	5.4	5.3	5.5	6.0	5.2	5.6	5.3	4.5	5.3	5.4
decoration	5.7	5.5	5.4	5.2	5.9	5.5	5.6	4.8	4.95	5.4	5.3
cleanliness	5.4	5.7	5.4	5.6	5.6	5.7	5.5	5.5	5.4	5.4	5.5
view	5.4	5.9	5.2	5.7	6.1	5.5	5.7	5.0	5.2	5.5	5.5
	1.8	1.5	1.9	1.3	0.7	1.5	1.9	1.7	1.7	1.6	1.6

*P-value of Chi-Square test. P-values in bold refer to significant relationships at 5% level.

^a number of respondents may vary due to missing information.

Appendix B

Table B1

Means (SD) of IEQ variables composing IEQ Clusters.

PCA	1-not important;10-extremely important - mean (SD)	1	2	3	4
Sounds and smells	Sounds from inside	6.9 (2.0)	7.0 (1.0)	7.6 (2.2)	4.8 (2.2)
	Sounds from outside	6.8 (2.1)	6.8 (1.7)	6.9 (2.4)	4.4 (2.1)
	Smells	6.8 (2.0)	6.4 (1.7)	5.8 (2.7)	4.5 (2.4)
Windows	Natural light	9.6 (0.5)	7.6 (1.2)	9.3 (0.8)	8.7 (1.0)
	Presence of windows	9.7 (0.5)	7.6 (1.4)	9.2 (1.0)	8.8 (1.3)
Localized temperature	Temperature of the chair	6.5 (1.4)	5.4 (1.7)	2.2 (1.4)	4.5 (2.4)
	Temperature of my feet	8.2 (1.3)	7.0 (1.4)	5.9 (2.4)	8.4 (1.7)
Building systems	Ventilation and air freshness	8.0 (1.6)	7.5 (1.4)	8.1 (1.8)	8.2 (1.4)
	Temperature	8.5 (1.0)	7.6 (1.1)	8.0 (1.5)	8.8 (1.0)
	Artificial light	8.0 (1.2)	7.0 (1.4)	6.8 (2.0)	4.5 (1.8)

Table B2

IEQ preferences clusters.

IEQ perception in past month mean (SD)	IEQ preferences clusters				p-value
	EC1 -123 (28.7%)	EC2 -143 (33.4%)	EC3 -109 (25.4%)	EC4 -53 (12.3%)	
Temperature general	5.1 (1.4)	5.2 (1.2)	5.1 (1.7)	5.1 (1.3)	0.993
temperature too cold vs too hot	3.5 (0.9)	3.6 (0.8)	3.5 (0.9)	3.6 (0.9)	0.674
temperature varies too much vs too little	3.9 (0.8)	4.0 (0.8)	3.8 (0.9)	3.8 (0.7)	0.456
air too drafty vs too still	4.7 (1.2)	4.6 (0.8)	4.5 (1.2)	4.6 (1.3)	0.525
too humid vs too dry	4.3 (0.7)	4.4 (0.8)	4.4 (1.0)	4.4 (0.9)	0.751
too stuffy vs too fresh	4.7 (1.1)	4.5 (1.1)	4.6 (1.4)	4.7 (1.4)	0.426
too smelly vs odourless	5.3 (1.1)	5.2 (1.0)	5.2 (1.4)	5.5 (1.2)	0.480
air quality unsatisfactory vs satisfactory	5.2 (1.4)	5.2 (1.1)	5.3 (1.5)	5.5 (1.2)	0.606
natural light	5.3 (1.6)	5.1 (1.3)	5.6 (1.5)	5.9 (1.1)	0.007
glare	5.1 (1.6)	5.1 (1.4)	5.3 (1.5)	5.2 (1.4)	0.669
artificial light	4.7 (1.5)	4.8 (1.3)	4.6 (1.8)	4.9 (1.3)	0.759
light overall	5.1 (1.4)	5.2 (1.2)	5.4 (1.4)	5.6 (1.1)	0.090
noise from outside	4.9 (1.5)	5.1 (1.3)	4.7 (1.8)	5.4 (1.4)	0.040
noise from building services	5.5 (1.4)	5.3 (1.2)	5.4 (1.6)	5.6 (1.1)	0.589
noise from inside	5.2 (1.5)	5.0 (1.4)	5.1 (1.8)	5.5 (1.3)	0.288
noise overall	5.2 (1.3)	5.1 (1.1)	4.9 (1.6)	5.4 (1.4)	0.215
vibration	5.9 (1.2)	5.7 (1.0)	5.7 (1.4)	5.9 (1.0)	0.385
Health in the last year %	EC1	EC2	EC3	EC4	p-value
Asthma	3.6	5.3	7.8	6	0.573
Bronchitis	0	3	2	0	0.720
wheezing	5.4	3.8	5.9	8	0.685
Other respiratory problems	3.6	5.3	3.9	4	0.639
Hay fever	32.4	26.3	30.4	38	0.361
Rhinitis	32.5	26.4	23.8	28	0.330
Eczema	20.7	18	13.7	22	0.827
Dermatitis	5.4	2.3	5	8	0.760
Other skin conditions	16.2	8.3	13	6	0.263
High lipids	2.7	11.4	10.9	8	0.062
Diabetes	1.8	3.8	2	4	0.887
High blood pressure	7.2	13.6	10.9	6	0.033
Other heart conditions	1.8	3	3.9	0	0.539
Migraine	13.5	6	18.6	20	0.078
Depression	14.4	6	10.9	10	0.064
Anxiety	24.3	6.8	20.8	18	0.000
Psychiatric problems	8.1	4.5	7.9	2	0.865

(continued on next page)

Table B2 (continued)

	IEQ preferences clusters				
Other conditions	18.9	6.8	13	10	0.173
Covid	13.7	14.9	26.5	9.1	0.036
Last month symptoms at least once/3 weeks %	EC1	EC2	EC3	EC4	p-value
Dry eyes	35.1	33.3	46.2	46	0.008
Watery or itchy eyes	31.6	26.6	34.6	34	0.066
Blocked or stuffy nose	45.6	51.9	46.2	36	0.453
Runny nose	36.8	32.6	33.7	32	0.743
Sneezing	58.8	65.9	60.6	68	0.906
Dry or sore throat	34.2	29.9	34.6	32	0.796
Lethargy	58.8	51.9	60.6	53.1	0.134
Headaches	50.9	41.5	49.5	44	0.387
breathing difficulty	14.9	11.9	16.3	8	0.453
Personal gender	EC1	EC2	EC3	EC4	p-value
Male	53.7	79.6	60.6	56.6	0.000
Female	45.5	20.4	38.5	41.5	
Prefer not to answer	0.8	0	0.9	1.9	
Age					0.069
Mean (SD)	40.7 (12.2)	44.3 (12.3)	41.0 (12.2)	42.4 (10.6)	
Min-max	21–66	20–68	21–66	26–65	
Physical activity Yes	84.6	83.9	90.7	81.1	0.312
Smokes; yes	34.1	32.9	43.1	52.8	0.208
Alcohol consumption; yes	86.2	93.7	93.6	79.2	0.000
Lockdown workspace					0.039
Home	82.9	71.1	84.4	77.4	
Office	17.1	28.9	15.6	22.6	
Interaction with Workspace					
Control of office; 1:none vs 7:high mean(SD)	EC1	EC2	EC3	EC4	p-value
temperature	5.3 (1.6)	5.2 (1.6)	5.6 (1.7)	5.5 (1.5)	0.268
Ventilation	5.2 (1.8)	4.8 (1.8)	5.4 (1.9)	5.4 (1.8)	0.069
Shading	5.7 (1.6)	5.4 (1.6)	5.3 (1.9)	6.0 (1.2)	0.051
Lighting	5.6 (1.6)	5.0 (1.7)	5.4 (1.8)	5.7 (1.4)	0.033
Noise	3.5 (1.5)	3.7 (1.4)	3.4 (1.7)	3.8 (1.7)	0.261
Satisfaction with workspace unsatisfied vs satisfied	EC1	EC2	EC3	EC4	p-value
privacy	5.8 (1.4)	5.5 (1.3)	5.7 (1.7)	6.1 (1.1)	0.095
layout	5.4 (1.4)	5.3 (1.2)	5.2 (1.7)	5.6 (1.4)	0.370
decoration	5.4 (1.4)	5.3 (1.2)	5.1 (1.6)	5.6 (1.1)	0.120
cleanliness	5.6 (1.3)	5.3 (1.1)	5.6 (1.3)	5.6 (1.2)	0.111
view	5.6 (1.4)	5.2 (1.5)	5.6 (1.7)	5.8 (1.2)	0.061
Workspace characteristics	EC1	EC2	EC3	EC4	p-value
Job type					0.069
Fulltime	70.2	81.3	80.4	68.0	
Part-time	29.8	18.7	19.6	32.0	
Workspace type					0.939
Single person private office	52.6	48.9	50.0	44.0	
Shared private office	18.4	16.5	26.5	34.0	
Open space with partition	4.4	8.3	2.9	4.0	
Open space without partitions	14.0	20.3	10.8	8.0	
Flexible space. I go to different spaces	7.0	3.0	3.9	6.0	
Other. specify	3.5	3.0	5.9	4.0	
Window presence	91.9	93	93.6	94.3	0.477
Aspects to work better importance: 1: not important at all; 10: extremely important					
Chair heating	3.4 (2.2)	3.4 (2.0)	1.9 (1.5)	2.6 (2.0)	0.000
Chair back rest heating	3.3 (2.3)	3.4 (2.2)	1.9 (1.8)	2.8 (2.2)	0.000
Desk heating	3.3 (2.3)	3.3 (2.1)	1.8 (1.4)	2.8 (2.3)	0.000
Desk lamp	6.7 (2.6)	5.7 (2.5)	5.8 (3.0)	4.9 (3.3)	0.006
Personal ventilation and fresh air at desk	6.7 (2.4)	6.5 (2.9)	7.0 (2.5)	6.9 (2.4)	0.025
Control of surrounding sound	7.3 (1.9)	7.0 (1.5)	7.4 (2.3)	5.8 (2.2)	0.000
Control of shading in room	7.9 (1.8)	7.3 (1.8)	7.5 (1.9)	7.1 (2.4)	0.065
Control of ventilation in room	7.9 (1.6)	7.0 (1.4)	7.8 (1.9)	7.7 (1.7)	0.000
Control of temperature in room	8.5 (1.2)	7.6 (1.2)	7.9 (1.8)	8.4 (1.1)	0.000
Headphones	6.6 (2.8)	5.9 (2.4)	6.4 (2.9)	5.5 (3.0)	0.022
Presence of plants	7.0 (2.4)	6.1 (2.3)	6.4 (2.9)	5.8 (3.0)	0.005

Appendix C

Table C1
Means (SD) of psychosocial variables composing Psychosocial Clusters.

PCA	1-not important;10-extremelly important - MEAN (SD)	1	2	3	4	5	6
Personalization of the place	Ability to adapt or control the place	7.4 (1.4)	6.9 (2.8)	8.4 (1.1)	6.7 (1.5)	5.2 (1.7)	7.4 (1.9)
	Privacy	7.1 (1.3)	6.3 (2.9)	8.6 (1.2)	7.0 (1.4)	5.4 (2.0)	8.3 (1.8)
	Bonding or identifying with the place	7.3 (1.4)	6.2 (3.1)	8.1 (1.2)	5.7 (1.5)	4.7 (2.1)	5.5 (2.6)
Ergonomics and hygiene	Chair type	7.8 (0.9)	4.2 (2.2)	9.2 (0.9)	7.8 (1.1)	9.3 (0.9)	8.8 (1.3)
	Amenities (desk size, monitor size, etc)	7.6 (0.8)	6.2 (2.2)	9.4 (0.6)	8.2 (1.0)	9.4 (0.8)	8.9 (1.2)
	Cleanliness	7.7 (1.1)	6.3 (2.3)	8.7 (1.1)	7.1 (1.3)	8.0 (1.3)	7.3 (2.2)
Size and spaces	Presence and company of others	7.9 (1.2)	4.8 (2.5)	7.5 (1.5)	5.8 (1.6)	7.7 (1.5)	3.0 (1.9)
	Size of the room	7.1 (1.2)	4.8 (2.4)	7.0 (1.6)	5.1 (1.4)	5.9 (1.9)	4.0 (1.9)
	Storage	5.8 (2.0)	4.0 (2.9)	7.1 (2.0)	4.6 (2.0)	4.8 (2.2)	4.1 (2.6)

Table C2
Psychosocial preferences comfort clusters.

IEQ perception in past month mean (SD)	Psychosocial Clusters						p-value
	PC1	PC2	PC3	PC4	PC5	PC6	
	63 (14.8)	42 (9.9)	67 (15.8)	104 (24.5)	65 (15.3)	83 (19.5)	
Temperature general	5.4 (1.2)	4.7 (1.7)	5.2 (1.5)	5.3 (1.2)	5.1 (1.3)	4.9 (1.7)	0.296
temperature too cold vs too hot	3.8 (0.8)	3.3 (0.8)	3.5 (0.9)	3.6 (0.7)	3.7 (0.9)	3.4 (0.9)	0.104
temperature varies too much vs too little	3.9 (0.7)	3.7 (1.0)	3.9 (0.8)	3.9 (0.9)	3.9 (0.5)	3.9 (1.0)	0.956
air too drafty vs too still	4.5 (1.1)	4.5 (1.1)	4.6 (1.4)	4.3 (0.8)	4.5 (1.2)	4.7 (1.2)	0.890
too humid vs too dry	4.4 (0.7)	4.2 (0.9)	4.4 (0.9)	4.7 (1.1)	4.2 (0.8)	4.3 (0.7)	0.673
too stuffy vs too fresh	4.6 (1.1)	4.7 (1.3)	4.6 (1.2)	5.0 (1.2)	4.6 (1.6)	4.5 (1.3)	0.952
too smelly vs odourless	5.3 (1.0)	5.4 (1.2)	5.3 (1.2)	5.2 (1.2)	5.2 (1.2)	5.4 (1.4)	0.458
air quality unsatisfactory vs satisfactory	5.3 (1.1)	5.4 (1.4)	5.1 (1.3)	5.4 (1.3)	5.0 (1.5)	5.3 (1.6)	0.852
natural light	5.3 (1.2)	5.3 (1.8)	5.5 (1.4)	5.2 (1.3)	5.2 (1.7)	5.4 (1.4)	0.973
glare	4.8 (1.4)	5.7 (1.6)	5.1 (1.5)	5.2 (1.4)	5.4 (1.4)	5.3 (1.7)	0.094
artificial light	4.8 (1.4)	5.0 (1.8)	4.7 (1.6)	4.9 (1.5)	4.5 (1.6)	4.5 (1.5)	0.616
light overall	5.3 (1.1)	5.2 (1.5)	5.2 (1.4)	5.3 (1.2)	5.1 (1.5)	5.2 (1.5)	0.941
noise from outside	5.1 (1.3)	4.3 (1.9)	4.9 (1.5)	5.0 (1.4)	5.2 (1.5)	4.9 (1.8)	0.269
noise from building services	5.4 (1.2)	5.9 (1.1)	5.3 (1.4)	5.5 (1.3)	5.6 (1.4)	5.4 (1.7)	0.710
noise from inside	5.0 (1.2)	5.3 (1.6)	5 (1.7)	5.2 (1.4)	5.2 (1.4)	5.4 (1.7)	0.790
noise overall	5.0 (1.1)	5.0 (1.4)	5.1 (1.5)	5.2 (1.1)	5.3 (1.1)	5.2 (1.4)	0.779
vibration	5.6 (1.1)	5.7 (1.5)	5.8 (1.3)	5.8 (1.1)	5.9 (1.1)	6.0 (1.3)	0.665
Health in the last year %	PC1	PC2	PC3	PC4	PC5	PC6	p-value
Asthma	6.0	7.4	3.0	8.6	2.6	6.8	0.445
Bronchitis	7.1	1.2	3.7	1.0	2.5	0	0.461
wheezing	2.4	0	5	9.9	5.3	8.5	0.873
Other respiratory problems	3.6	0	4	6.2	2.6	1.7	0.618
Hay fever	25.3	37	32	27.2	52.6	30.5	0.100
Rhinitis	26.5	25.8	32	27.2	18.4	32.2	0.074
Eczema	12.0	14.8	18.0	21.0	28.9	22.0	0.295
Dermatitis	4.8	0	5.0	5.0	7.9	3.4	0.800
Other skin conditions	8.4	3.7	15.2	12.5	23.7	3.4	0.056
High lipids	8.5	11.1	7.0	7.5	7.9	6.8	0.589
Diabetes	3.6	0	2.0	2.5	2.5	5.1	0.347
High blood pressure	13.4	11.1	11.0	8.8	5.3	8.5	0.312
Other heart conditions	6.0	3.7	3.0	0	0	1.7	0.696
Migraine	6.0	7.4	16.0	11.1	15.8	23.7	0.261
Depression	8.4	3.7	13.1	12.3	5.3	8.5	0.618
Anxiety	15.7	7.4	22.0	15.0	15.8	18.6	0.900
Psychiatric problems	3.6	7.4	4.0	9.9	2.6	10.2	0.952
Other conditions	9.6	3.7	13.1	8.9	13.2	15.3	0.156
Covid	20.8	16.7	14.1	15.9	22.6	13.5	0.785
Last month symptoms at least once/3 weeks %	PC1	PC2	PC3	PC4	PC5	PC6	p-value
Dry eyes	38.1	46.4	36.6	38.6	47.4	30	0.810
Watery or itchy eyes	31.0	32.1	35.6	27.7	39.5	15	0.017
Blocked or stuffy nose	46.4	57.1	41.6	53.0	47.4	46.7	0.803
Runny nose	33.3	35.7	34.7	38.6	39.5	28.3	0.980
Sneezing	67.9	67.9	58.4	68.7	63.2	56.7	0.728
Dry or sore throat	32.1	42.9	34.7	33.7	26.3	23.3	0.031
Lethargy	50.0	71.4	51.5	61.4	55.3	61.7	0.230
Headaches	50.0	32.1	52.5	46.3	36.8	45.0	0.382
breathing difficulty	15.5	17.9	15.8	9.8	10.5	8.3	0.836
Personal gender	PC1	PC2	PC3	PC4	PC5	PC6	p-value
Male	62.5	57.1	53.7	69.8	63.4	77.4	0.045
Female	36.4	42.9	45.4	29.1	36.6	22.6	
Prefer not to answer	1.1	0	0.9	1.2	0	0	

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Table C2 (continued)

IEQ perception in past month mean (SD)	Psychosocial Clusters						p-value
	PC1	PC2	PC3	PC4	PC5	PC6	
	63 (14.8)	42 (9.9)	67 (15.8)	104 (24.5)	65 (15.3)	83 (19.5)	
Age							0.051
Mean (SD)	44.23 (11.9)	44.1 (11.4)	41.4 (12.4)	42.9 (11.8)	37.2 (11.8)	43.2 (12.5)	
Min-max	23–68	25–61	21–66	20–66	23–63	23–65	
Physical activity Yes	80.9	89.3	79.6	89.4	90.2	93.5	0.075
Smokes; yes	42.7	21.4	42.6	36	39	33.9	0.190
Alcohol consumption; yes	88.8	82.1	88.9	94.2	85.4	88.7	0.137
Lockdown workspace							0.000
Home	68.5	92.9	74.1	86.0	68.3	93.5	
Office	31.5	7.1	25.9	14.0	31.7	6.5	
Interaction with Workspace							
Control of office; 1: none vs 7: high mean(SD)	PC1	PC2	PC3	PC4	PC5	PC6	p-value
temperature	5.2 (1.5)	5.4 (1.4)	5.3 (1.6)	5.3 (1.5)	5.2 (1.9)	5.6 (1.7)	0.774
Ventilation	5.2 (1.6)	5.3 (1.7)	5.1 (1.8)	5.1 (1.8)	4.5 (2.3)	5.5 (1.7)	0.207
Shading	5.3 (1.6)	5.7 (1.6)	5.6 (1.6)	5.4 (1.7)	5.2 (1.9)	5.8 (1.6)	0.454
Lighting	5.1 (1.7)	5.8 (1.4)	5.4 (1.7)	5.4 (1.6)	5.1 (1.9)	5.9 (1.5)	0.078
Noise	3.9 (1.5)	3.7 (1.9)	3.4 (1.7)	3.6 (1.4)	3.2 (1.6)	3.6 (1.7)	0.140
Satisfaction with office unsatisfied vs satisfied	PC1	PC2	PC3	PC4	PC5	PC6	p-value
privacy	5.4 (1.4)	6.4 (1.1)	5.6 (1.7)	5.8 (1.3)	6.0 (1.1)	6.0 (1.5)	0.10
layout	5.1 (1.3)	5.6 (1.3)	5.1 (1.6)	5.3 (1.4)	5.4 (1.3)	5.7 (1.4)	0.204
decoration	5.4 (1.2)	5.4 (1.4)	5.0 (1.5)	5.3 (1.3)	5.7 (1.2)	5.6 (1.3)	0.135
cleanliness	5.4 (1.0)	5.7 (1.4)	5.6 (1.2)	5.3 (1.1)	5.7 (1.1)	5.4 (1.5)	0.631
view	5.5 (1.4)	5.9 (1.7)	5.5 (1.5)	5.5 (1.3)	5.4 (1.8)	5.3 (1.8)	0.878
Workspace characteristics	PC1	PC2	PC3	PC4	PC5	PC6	p-value
Job type							
Fulltime	66.3	92.6	75.0	80.5	78.9	78.3	
Part-time	33.7	7.4	25.0	19.5	21.1	21.7	
Workspace type							0.66
Single person private office	38.6	48.1	50.0	58.5	34.2	64.4	
Shared private office	24.1	18.5	20.0	18.3	34.2	16.9	
Open space with partition	8.4	3.7	4.0	3.7	13.2	3.4	
Open space without partitions	18.1	11.1	16.0	12.2	10.5	10.2	
Flexible space. I go to different spaces	6.0	11.1	5.0	6.1	0	3.4	
Other. specify	4.8	7.4	5.0	1.2	7.9	1.7	
Window presence	93.3	96.4	90.7	95.3	92.7	95.2	0.328
Aspects to work better importance: 1: not important at all; 10: extremely important							
Chair heating	3.4 (2.0)	1.8 (1.9)	3.5 (2.3)	2.6 (1.7)	2.2 (1.7)	2.5 (2.1)	0.001
Chair back rest heating	3.5 (2.1)	1.8 (1.8)	3.5 (2.4)	2.6 (2.0)	2.3 (1.8)	2.5 (2.3)	0.006
Desk heating	3.4 (2.0)	1.8 (1.5)	3.4 (2.2)	2.6 (1.9)	2.3 (1.8)	2.1 (2.3)	0.000
Desk lamp	5.7 (2.4)	5.8 (3.1)	6.5 (2.9)	5.8 (2.5)	4.4 (2.8)	6.2 (3.0)	0.002
Personal ventilation and fresh air at desk	6.5 (2.2)	6.0 (3.0)	7.1 (2.3)	6.5 (1.9)	6.6 (2.4)	6.8 (2.2)	0.330
Control of surrounding sound	6.7 (1.7)	6.0 (3.0)	7.6 (1.9)	6.7 (1.5)	6.6 (2.1)	7.5 (2.1)	0.000
Control of shading in room	7.8 (1.2)	6.6 (2.4)	8.0 (1.7)	7.0 (2.0)	7.2 (2.0)	7.5 (2.2)	0.003
Control of ventilation in room	7.2 (1.6)	7.3 (2.0)	8.1 (1.6)	7.0 (1.5)	7.7 (1.4)	7.8 (1.7)	0.001
Control of temperature in room	7.8 (1.1)	7.7 (2.2)	8.5 (1.2)	7.6 (1.4)	8.0 (1.7)	8.3 (1.5)	0.000
Headphones	5.9 (2.4)	6.2 (2.9)	6.7 (2.6)	5.9 (2.7)	5.7 (3.2)	6.4 (3.0)	0.056
Presence of plants	6.6 (2.3)	5.2 (2.9)	7.0 (2.4)	6.0 (2.3)	6.5 (2.9)	6.3 (3.2)	0.034

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