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DOI
10.1016/j.buildenv.2020.106860

Publication date
2020

Document Version
Final published version

Published in
Building and Environment

Citation (APA)
Kim, D. H., & Bluyssen, P. M. (2020). Clustering of office workers from the OFFICAIR study in The Netherlands based on their self-reported health and comfort. *Building and Environment*, *176*, Article 106860. https://doi.org/10.1016/j.buildenv.2020.106860

Building and Environment 176 (2020) 106860

Contents lists available at ScienceDirect

Building and Environment

journal homepage: http://www.elsevier.com/locate/buildenv

Clustering of office workers from the OFFICAIR study in The Netherlands based on their self-reported health and comfort

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ARTICLE INFO

Keywords:
Self-reported health and comfort
Building-related symptoms
Office workers
Indoor environmental quality
TwoStep cluster analysis

ABSTRACT

The growing field of indoor health and comfort studies recently shifted from predicting the average comfort and wellbeing of a large population into identifying the needs of individuals in different scenarios. This study aimed to identify different profiles of office workers in the Netherlands who took part in the OFFICAIR study, based on their self-reported health and comfort. Associations of respondents' health and comfort with gender and type of office indicated that female occupants experienced significantly higher numbers of building-related symptoms and consistently lower satisfaction levels of their office environment than male occupants. Workers in open space offices without partitions reported lower satisfaction and suffered from building-related symptoms more frequently than occupants in single person offices. 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. While the first group was by far the healthiest, significant higher risks for building-related symptoms such as dry eyes (OR: 3.38), dry skin (OR: 2.87) and watering, itchy eyes (OR: 2.7) were identified for the unhealthy group than for the moderate healthy group. The results confirm the need of an integrated approach to better understand moderate and unhealthy groups in order to provide customised solutions for individuals with different complaints and needs.

1. Introduction

Office workers spend a large part of their time inside the buildings in which they work, therefore office buildings should ensure comfort, health and wellbeing for their occupants'. In fact, 'a healthy, energy-efficient and comfortable indoor environment' has been researched by many studies for over several decades [1]. Previous studies clearly suggest a direct link between building design (including indoor building conditions) and human health and well-being of the occupants [1–6]. For example, an increase in thermal satisfaction raised comfort expectations of other indoor environmental quality (IEQ) factors, and had a positive effect on occupants' productivity in a study performed by Geng et al. [7]. In several studies, employees with higher lighting appraisals reported a better mood and improved health and well-being at the end of their workday [8,9]. It has been shown that lighting quality plays an important role in the control of the day-night rhythm [10,11]. Several indoor air quality (IAQ) studies highlighted various health-related issues reported by some of the building occupants who were dissatisfied with IAQ [3,12,13]. Unfortunately, many of these findings have not yet been reflected in present-day IEQ guidelines to prevent or reduce health and comfort effects of occupants.

With respect to the relative impact (or importance) of different indoor environmental conditions on office workers' level of overall satisfaction with the office environment, mixed outcomes are often found [14,15]. The most important (or influential) environmental aspect can differ per study: the amount of space and acoustics in Ref. [16], air quality in Refs. [17,18], thermal environment in Refs. [19–23], privacy and acoustics in Refs. [24], and acoustics and office layout in Ref. [25]. There are many differences between the studies listed above such as the study design (e.g. building type, location and construction date) [2,26] and social-cultural factors [19,27], that may account for these inconsistent findings. It is also suggested that people experience and complain about certain building-related symptoms even when their workspaces comply with the guidelines [2,28].

The lack of consistency in some findings are fundamentally due to the fact that the built environment and its indoor environment with occupants is a complex system with many interrelations, that can be linear or non-linear [29,30]. Yet, IEQ is still often assessed mainly on

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https://doi.org/10.1016/j.buildenv.2020.106860
Received 13 January 2020; Received in revised form 19 March 2020; Accepted 20 March 2020
Available online 8 April 2020

single dose-related indicators, and is developed for the average occupant, ignoring the fact that we are dealing with individuals in different scenarios and situations. To overcome the current difficulties, 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 human and environmental level [28]. The goal of the integrated analysis approach is 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 average comfort and health of a large population. To achieve this, profiling of occupants based on their comfort, behaviours and needs of IEQ in certain scenarios and situations is essential.

Several studies have clustered occupants based on their behaviours and preferences with different methods. For example, the K-mean clustering algorithm was used to profile occupants based on their lighting control behaviours and dimming level preferences [31]; and it was used to profile office workers based on electricity load patterns [32], HVAC-schedules [33] and thermal preferences [34]. The TwoStep clustering algorithm has been applied particularly in recent studies. Six clusters of primary school children in the Netherlands based on their preferences and needs of IEQ in their classrooms were identified [35]; and five different archetypes of home occupants in the Netherlands based on their comfort behaviours and energy use pattern were identified [36,37]. All of the studies listed above clearly indicate that people can indeed differ in their preferences and needs and that it seems possible to distribute them into clusters (profiling).

Therefore, this study started with questioning whether profiles of office workers can also be identified based on their self-reported health and comfort regarding their office environments. If so, what would be the characteristics of the profiles? In order to answer these questions, this study used existing survey data (from the OFFICAIR study) [2], with a particular focus on the office workers studied in the Netherlands. Because self-reported health and comfort of the respondents in the office buildings in the Netherlands from the OFFICAIR study have not been reported yet, the health and comfort data and their possible associations with some demographic profiles such as gender and type of office, were explored first. Then, clustering was performed.

2. Methodology

2.1. Study population and design

OFFICAIR was a European research project, which involved collecting data from 167 office buildings in eight European countries (Greece, France, Finland, Hungary, Italy, Portugal, Spain and the Netherlands) during the winter of 2011–2012, and questionnaire data from 7441 office workers. The procedure of this cross-sectional study is described in detail elsewhere [2], and is therefore only briefly summarized here. This study focuses on the results from the Netherlands, in which in total 1014 office workers from 20 different office buildings participated. All the buildings shared the following characteristics: (1) new or recently retrofitted buildings (less than 10 years old) at the start of the study, (2) buildings had been operating in their current form for a minimum of 1 year prior to the start of the study, (3) no major renovation was planned within a year at the start of the study.

2.2. Worker questionnaire

Self-reported data, collected by questionnaires, were used to investigate office workers' health and comfort. Health symptoms and experienced comfort of the respondents in this study are explained and summarized in Table 1 and Table 2, respectively.

Concerning health symptoms (a total of 20), participants were asked: *"During the past four weeks, on how many days did you experience each of the following symptoms when you were at work at your workstation (including today)?"* These questions were answered by occupants using a five-point scale. Health symptoms that office workers *frequently* experienced during the past month were the primary focus of this study. *Frequent* occurrence was defined as 'greater than or equal to 1–3 days per week in the last 4 weeks'. Then the item was dichotomized into: "*Did you experience the following symptoms frequently during the past four weeks?*" (Yes/No) (see Table 1). In the result section, both values ('frequently experienced' and 'experienced') are presented (see Fig. 1) which allows comparison of the results with the complete dataset of the OFFICAIR study [2,38].

Table 1
Self-reported health symptoms and the scales used.

Health symptoms	Original scale (5-point) answered by the subjects	Dichotomized scale used by others [2, 38]	Dichotomized scale used in this study
Dry eyes Watering, itchy eyes Burning, irrigated eyes Blocked, stuffy nose Runny nose Dry, irritated throat Chest tightness, breathing difficulty Flu-like symptoms Dry skin Rash, irritated skin Headache Lethargy, unusual tiredness Wheezing Cough Sneezing Tachycardia Irregular heart beats Bradycardia Phlegm, mucus Any other symptoms	Never (1) Not in the last 4 weeks (2) 1–3 days in the last 4 weeks (3) 1–3 days per week in the last 4 weeks (4) Every or almost every workday (5)	Yes, I experienced the symptom in the past 4 weeks (3–5)	Yes, I *frequently* experienced the symptom in the past 4 weeks (4–5)

For comfort with environmental conditions (in total 17), participants were asked: "*How would you describe the typical indoor conditions in your office environment during the past four weeks?*" These questions were originally answered by the occupants using a seven-point scale. In previous publications on the OFFICAIR results [2,38] the first three values (of the seven-point scale) were used to define dissatisfaction, whereas in another publication the first two values were used to define clear dissatisfaction [39]. In this study the first two values were converted into the percentages of office workers who expressed *clear* dissatisfaction with the indoor environmental conditions (see Table 2).

2.3. Participants

3569 invitation e-mails were sent, 1319 respondents started and 1022 submitted the questionnaire. A total of 1014 completed questionnaires were found to be valid and therefore were included in this study. Table 3 shows some characteristics of the respondents. Workers were balanced in terms of gender (ratio male/female: 1.02). The mean (standard deviation) age of the respondent was 43.8 (10.1) years. Most of workers (69%) had a university degree. Concerning their life style,

Table 2
Self-reported dissatisfaction with environmental conditions and the scales used.

	Conditions	Original scale (7-point) answered by the subjects	Dichotomized scale used by others [2,38]	Dichotomized scale used in this study
Overall IEQ	Noise quality Air quality Light quality Thermal comfort Overall comfort	Unsatisfactory (1) to Satisfactory (7)	Dissatisfaction (1–3)	Clear dissatisfaction (1–2)
Specific IEQ	Temperature	Varies too much during the day (−3) to Not enough variation (3)	Variation of temperature (−3 to −1) Not enough variation (1–3)	Variation of temperature (−3 to −2) Not enough variation (2–3)
	Temperature	Too cold (−3) to Too hot (3)	Cold temperature (−3 to −1) Hot temperature (1–3)	Cold temperature (−3 to −2) Hot temperature (2–3)
	Air movement	Draughty (−3) to Still (3)	Draughty air (−3 to −1)	Draughty air (−3 to −2)
	Air quality	Humid (−3) to Dry (3)	Humid air (−3 to −1) Dry air (1–3)	Humid air (−3 to −2) Dry air (2–3)
	Air quality	Stuffy (1) to Fresh (7)	Stuffy air (1–2)	Stuffy air (1–2)
	Air quality	Smelly (1) to Fresh (7)	Smelly air (1–2)	Smelly air (1–2)
	Reflection or glare	Glare (1) to No glare (7)	Glare or reflection (1–3)	Glare or reflection (1–2)
	Natural light Artificial light Noise from outside Noise from building system Noise from inside	Unsatisfactory (1) to Satisfactory (7)	Dissatisfaction (1–3)	Clear dissatisfaction (1–2)

58% and 29% were never and former smokers, respectively. 14% reported to smoke currently and 81% consumed alcohol. With regard to type of offices, 45% of the participants worked in open space offices (9% with partitions and 36% without partitions) and 54% worked in private offices (18% single person office and 35% shared office). A median of 12 (interquartile range (IQR) 8–20) persons was reported for open spaces with partitions and a median of 20 (IQR 10–30) persons was reported for open spaces without partitions.

2.4. Data management and analysis

The percentage of occupants who expressed clear dissatisfaction was calculated for each of the 19 variables (converting the dichotomized scale increased the number of conditions from 17 to 19). Percentage of dissatisfied (defined as the cumulative total of the first two points on the seven-point satisfaction scale) is regarded as a meaningful and practical metric in IEQ research [3] and has been adopted in several other studies and therefore is directly comparable to that used by other researchers [3,40,41]. A series of multivariate logistic regression analyses were performed to investigate the association between dissatisfaction with the different environmental conditions and personal and work-related factors. The same approach was used to investigate the relationship between the 20 self-reported symptoms and personal and work-related factors. The results of the logistic regression models are reported as adjusted odds ratio (AOR). The AOR represents the ratio of the odds of a particular outcome occurring in one group over the odds of it occurring in another group.

The TwoStep cluster analysis approach was then used to categorize the office workers based on their self-reported health and comfort. The TwoStep cluster analysis was selected for the following reasons. First, it permits both continuous and categorical data to be analysed simultaneously. Second, optimal number of clusters are automatically selected by the method. Thirdly, the method is suitable for large data sets [42,43]. Several recent studies also showed that the TwoStep cluster analysis was an effective tool to cluster school children [35] and home occupants [36,37]. For the detailed setting of the TwoStep analysis, the option of optimum number of clusters, log-likelihood distance measure and Akaike's Information Criterion were selected. As suggested by Norušis [43], the following steps were performed to validate the final solution model. First, the silhouette measure of cohesion of the clusters were checked (value recommended to be above 0.0 and preferably 0.2). Second, Chi-square tests and t-tests were performed with categorical and continuous variables respectively: all variables in the solution needed to be statistically significant ($p < 0.05$). Third, predictor importance scores were checked (recommended to be greater than 0.02). Finally, a series of multivariate logistic regression analyses were performed again to compare the strength of the associations between different identified clusters and occupants' health and comfort quality. All of the statistical analysis used in this study were conducted using IBM SPSS 24.

3. Results

3.1. Health symptoms

In Fig. 1 the percentages of office workers having symptoms are presented. Three of the most prevalent symptoms for 'frequently experienced', (and 'experienced') were: 'dry eyes' (31% 'frequently experienced' and 47% 'experienced'), 'dry skin' (23% and 30%) and 'burning, irritated eyes' (18% and 29%). More than one-seventh of the workers in the Netherlands reported that they had 'frequently experienced' (and 'experienced') 'blocked nose' (17% and 30%), 'headache' (16% and 40%), 'dry, irritated throat' (16% and 27%) and 'sneezing' (14% and 24%) at their workstations during the last month. While 64% and 48% blamed no particular season or no particular of day, more than one in five of the workers (23% and 42%) answered that symptoms tended to be worst in the winter season and in the afternoon of a day, respectively. 76% of the workers believed that any of the experienced symptoms was due to their office environment.

Multivariate logistic regression analysis was conducted to investigate the associations between the 10 highest prevalent symptoms and confounding factors gender and type of office. Table 4 presents the adjusted odds ratios (OR) for each of the 10 symptoms. The outcome showed that female workers in the Netherlands had significantly more symptoms than male workers. 'Dry skin' showed the strongest association (36% vs. 10%; OR = 4.19, 95% CI = 2.89–6.08, $p < 0.001$) with female gender, followed by 'headache' (24% vs. 8%; OR = 3.00, 95% CI = 1.98–4.56, $p < 0.001$), 'dry eyes' (43% vs. 19%; OR = 2.77, 95% CI = 2.02–3.81, $p < 0.001$) and 'burning, irritated eyes' (25% vs. 11%; OR = 2.49, 95% CI = 1.69–3.64, $p < 0.001$). Additionally, associations of 'lethargy, unusual tiredness' (12% vs. 5%; OR = 2.1, 95% CI = 1.23–3.59, $p = 0.007$) 'dry, irritated throat' (21% vs. 11%; OR = 1.98, 95% CI = 1.33–2.96, $p < 0.001$) and 'sneezing' (OR = 1.51, 95% CI = 1.03–2.28, $p < 0.05$) with female gender were found. No association was found for 'headache', 'runny nose' and 'watering, itchy eyes'.

Respondents occupying an 'open space without partitions' were significantly associated with higher rates of four symptoms (headache, dry/irritated throat, dry eyes, dry skin) than respondents occupying a 'single person office' (Table 4). More specifically, the result showed that subjects who worked in an open space without partitions were 2.25 times more likely to experience 'headache' (24% vs. 9%' OR = 2.25, 95% CI = 1.23–4.11, $p = 0.008$) and 'dry, irritated throat' (22% vs. 10%'

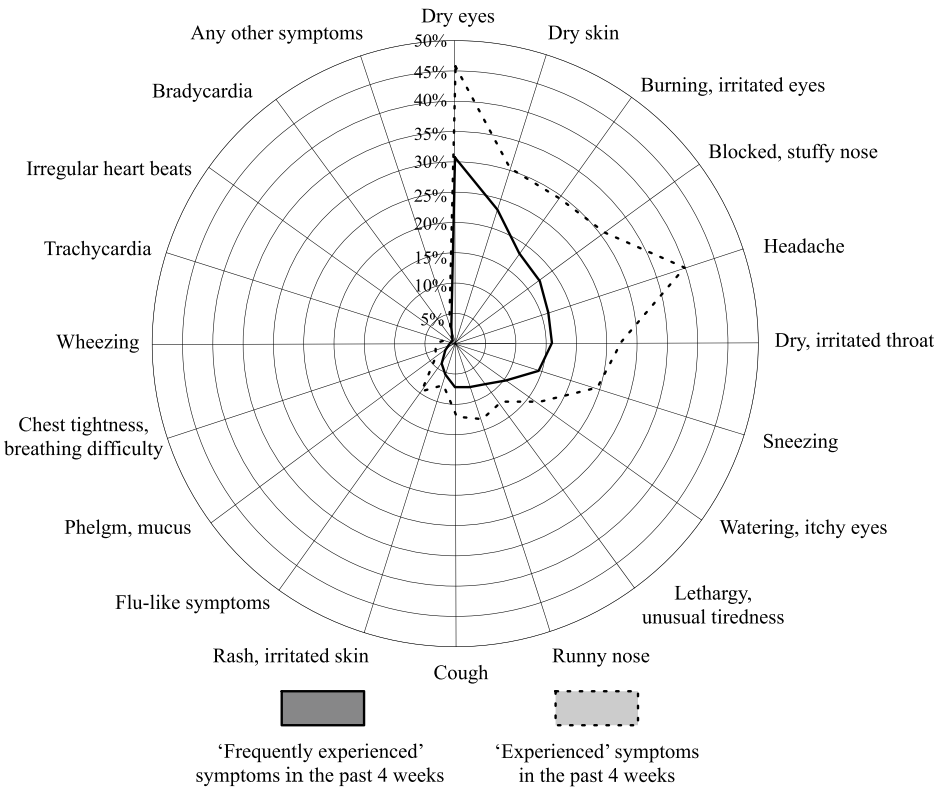

Fig. 1. Percentages of symptoms reported by office workers in the Netherlands (from the OFFICAIR study, n = 1014). The symptoms are presented in a descending and clockwise way.

Table 3
Characteristics of the workers from the office buildings studied in the Netherlands.

Characteristics	n[a] (%)
Personal	
Age	
<40	359 (35.4)
40-49	330 (32.5)
50 ≥	325 (32.1)
Gender	
Male	511 (50.4)
Female	503 (49.6)
Education background	
Master, PhD, or specialization	366 (36.3)
University, college, or equivalent	326 (32.3)
Professional	144 (14.3)
Secondary school	167 (16.6)
Primary school or less	5 (0.5)
Lifestyle	
Smoking status	
Current	136 (13.6)
Former	285 (28.6)
Never	576 (57.7)
Alcohol consumption (yes)	804 (80.5)
Office and work-related	
Type of work	
Managerial	217 (21.4)
Professional	324 (32.0)
Clerical-secretarial	251 (24.8)
Other	220 (21.7)
Type of office	
Single person private office	186 (18.4)
Shared private office	356 (35.2)
Open space with partitions	91 (9.0)
Open space without partitions	364 (36.0)
Other	13 (1.3)

[a] Number of office workers may vary due to missing information.

Table 4
Logistic regression analysis for association of frequent symptoms with gender and type of office.

Top 10 symptoms	Adjusted OR (95% CI)	
	Female vs. Male[a]	Open space without partitions vs. single person office[b]
Dry eyes	2.77 (2.02–3.81) ***	1.78 (1.14–2.78)*
Dry skin	4.19 (2.89–6.08) ***	1.82 (1.07–3.08)*
Burning, irritated eyes	2.49 (1.69–3.64) ***	NS
Blocked, stuffy nose	NS	NS
Headache	3.00 (1.98–4.56) ***	2.25 (1.23–4.11)**
Dry, irritated throat	1.98 (1.33–2.96) ***	2.25 (1.25–4.04)**
Sneezing	1.51 (1.03–2.28) *	NS
Watering, itchy eyes	NS	NS
Lethargy, unusual tiredness	2.1 (1.23–3.59) **	NS
Runny nose	NS	NS

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, NS = not significant ($p > 0.05$).
[a] Adjusted odds ratio implies controlling for age, type of office and type of work.
[b] Adjusted odds ratio implies controlling for gender, age, and type of work.

OR = 2.25, 95% CI = 1.25–4.04, $p = 0.007$) than workers from a single person office. No statistically significant relationships were found for 'single person office', 'shared office' and 'open space with partition', or for symptoms and age.

3.2. Perceived environmental conditions

The percentages of office workers expressing *clear* dissatisfaction (and dissatisfaction) is graphically presented for each of 19 environmental conditions in Fig. 2. Respectively, 14% and 31% of the respondents expressed 'clear dissatisfaction' and 'dissatisfaction' with overall comfort of their office environmental conditions (see Fig. 2). The highest dissatisfaction was reported for 'overall air quality' (respectively 29% clear dissatisfaction and 47% dissatisfaction), followed by 'overall thermal comfort' (24% and 45%), and 'overall noise quality' (18% and 34%). Relatively lower satisfaction rates were found for 'overall light quality' (13% and 25%), also seen in the levels of dissatisfaction for the specific conditions ('natural light' (17% and 27%), 'artificial light' (14% and 24%), and 'glare' (16% and 29%). More than half of the office workers (54% and 70%) reported clear dissatisfaction with 'dry air', whereas a very small number of workers (2% and 4%) reported complaints about 'humid air'. Clear dissatisfaction with 'stuffy air' (25% and 41%) 'draughty air movement' (17% and 29%), and 'smelly air' (12% and 22%) were reported. Almost one-third of the participants (31% and 47%) expressed dissatisfaction with 'noise from inside the building' (e.g. phone calls, colleagues chatting, and photocopiers). 21% (37%) of the workers found the indoor environment 'too cold', 13% (26%) 'too hot' and 21% (34%) reported that the temperature varied too much during the day in the past month.

The relationship of dissatisfaction with environmental conditions with gender and type of office was investigated by logistic regression analysis. Table 5 presents the adjusted odd ratios (OR) with 95% confidence intervals. Concerning gender effect, female workers significantly reported higher levels of clear dissatisfaction than male respondents for almost all of variables, except for 'humid air' and 'unsatisfactory noise from outside'. The strongest relationship with female workers was found for dissatisfaction with 'overall thermal comfort' (36% vs. 14%; OR = 3, 95% CI = 2.1–4.27, $p < 0.001$), followed by 'dry air' (67% vs. 42%; OR = 2.41, 95% CI = 1.8–3.23, $p < 0.001$) and 'unsatisfactory artificial light' (19% vs. 9%; OR = 2.32, 95% CI = 1.53–3.51, $p < 0.001$). Regarding perceived 'overall comfort', female workers were almost twice more likely to express clear dissatisfaction than male workers (19% vs. 10%; OR = 2.06, 95% CI = 1.36–3.14, $p < 0.001$).

Different types of offices were also found to be associated with perceived environmental conditions. Open space without partitions was significantly associated with higher rates of clear dissatisfaction on many of variables than in single person offices. Two variables that particularly showed the strongest relationship with 'open space without partition' were 'overall thermal comfort' (40% vs. 9%; OR = 5.43, 95% CI = 3.05–9.66, $p < 0.001$) and 'draughty air movement' (28% vs. 7%; OR = 5.39, 95% CI = 2.83–10.26, $p < 0.001$). Type of office was not found to be correlated with clear dissatisfaction with 'natural light' or 'artificial light'. Office workers in open spaces (either with partition or without partition) were more likely to express clear dissatisfaction with 'reflection or glare' than office workers in single person offices.

3.3. Clustering of office workers

The TwoStep cluster analysis resulted in three clusters with 909 workers (105 workers, as incomplete sample, were automatically excluded by the two-step cluster analysis). Initially, 18 variables (excluding 'overall comfort') were included and two variables (air–humid and noise–outside) were removed when a final cluster solution was achieved, as their prediction score was lower than 0.02 [10]. The final solution presents a silhouette measure of cohesion and separation of 0.3, which ensures that within and between-cluster distance is valid amongst the 16 variables, indicating variation between the variables. Comparison of means analysis ensured that the final 16 variables were statistically significant, and hence they varied between clusters. Additionally, the variables with the lowest score for predictor importance was found to have a rating of 0.07, above the recommended 0.02. The predict importance of these variables in the final solution were: air–dry (1.00), noise–inside (0.80), air–overall quality (0.60), noise–overall quality (0.37), light–overall quality (0.25), light–artificial (0.20), light–natural (0.13), air–stuffy (0.11), temperature–too much variation (0.10), temperature–too cold (0.07), light–glare (0.07), noise–building system (0.07), air–smelly (0.07), air–draughty (0.07). All of these variables were confirmed to be statistically significant related to the three clusters.

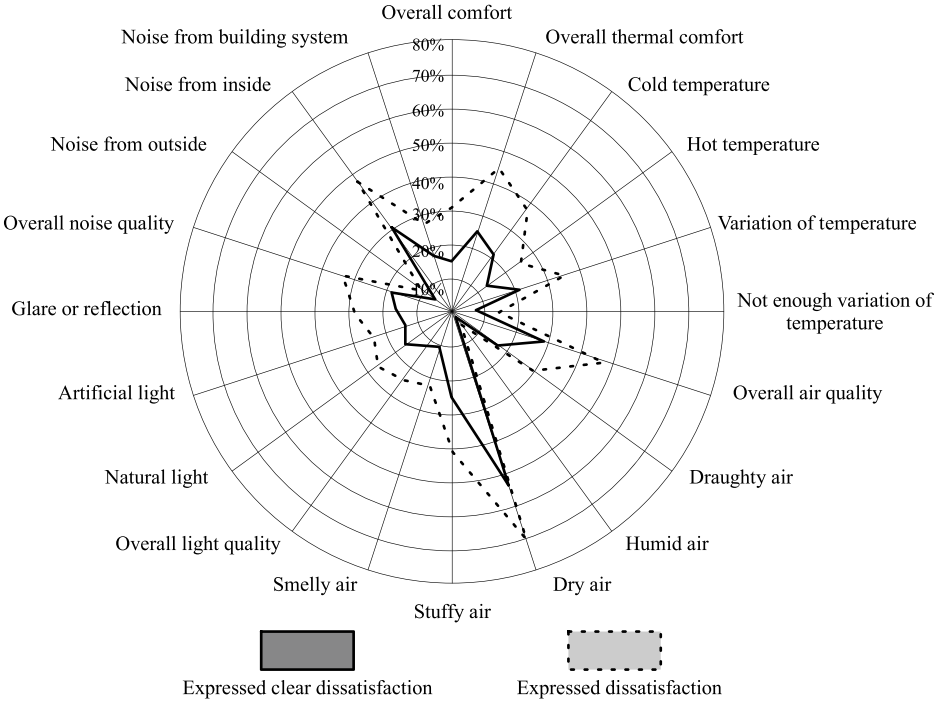

Fig. 2. Percentages of dissatisfaction of office workers for 20 indoor environmental conditions (from the OFFICAIR study, N = 1014). Note. Clear dissatisfaction indicates the bottom 2 scores on a scale of 1–7 and dissatisfaction is defined as values below '4' on a scale of 1–7.

Table 5
Logistic regression analysis for association of clear dissatisfaction of environmental conditions with gender and type of office.

Environmental variables	Adjusted OR (95% CI)		
	Female vs. Male[a]	Open space with partitions vs. Single person office[b]	Open space without partitions vs. Single person office[b]
Overall conditions			
Overall noise quality	1.81 (1.31–2.50)***	3.27 (1.62–6.62)***	3.69 (2.08–6.53)***
Overall air quality	1.84 (1.33–2.54)***	2.83 (1.50–5.32)**	4.04 (2.45–6.65)***
Overall light quality	2.12 (1.37–3.27)***	NS	2.31 (1.23–4.38)**
Overall thermal comfort	3.00 (2.10–4.27)***	2.20 (1.06–4.57)*	5.43 (3.05–9.66)***
Specific conditions			
Variation of temperature	1.86 (1.30–2.66)***	3.09 (1.50–6.34)**	3.56 (1.97–6.44)***
Cold temperature	2.09 (1.46–2.99)***	NS	NS
Hot temperature	1.76 (1.14–2.71)*	NS	NS
Draughty air	1.93 (1.30–2.85)***	2.63 (1.16–5.97)*	5.39 (2.83–10.26)***
Dry air	2.41 (1.80–3.23)***	3.65 (1.99–6.66)***	2.20 (1.47–3.27)***
Stuffy air	1.95 (1.41–2.71)***	NS	2.09 (1.26–3.46)**
Smelly air	1.70 (1.10–2.64)*	NS	NS
Natural light	1.81 (1.24–2.64)**	NS	NS
Artificial light	2.32 (1.53–3.51)***	NS	NS
Reflection or glare	1.50 (1.02–2.20)*	3.10 (1.47–6.55)**	2.95 (1.59–5.45)***
Noise from building system	1.82 (1.23–2.68)**	3.25 (1.58–6.68)**	4.18 (2.36–7.43)***
Noise from inside	1.77 (1.28–2.40)***	3.12 (1.73–5.69)***	3.77 (2.37–6.01)***
Overall comfort	2.06 (1.36–3.14)***	NS	3.06 (1.63–5.76)***

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, NS = not significant ($p > 0.05$).
[a] Adjusted odds ratio implies control for age, type of office and type of work.
[b] Adjusted odds ratio implies control for gender, age, and type of work.

Table 6 presents general characteristics of the office workers such as age, gender, type of office, type of work, perceived health and comfort for the three identified clusters. Mean age of the workers in each cluster showed no difference, while significant statistical difference in gender, type of office and type of work were noticed. In terms of perceived health and comfort, office workers from three clusters varied significantly. All of the variables in these categories showed statistically significant differences. To investigate the differences in their self-reported health and comfort more thoroughly, a series of multivariate regression analyses with controlling age, gender, type of office and type of work, were performed. Tables 7 and 8 present the adjusted odd ratios (OR) with 95% confidence intervals for association of three clusters with

Table 6
Descriptive statistics of the three identified clusters of office workers (n = 909).

Characteristics	Total sample (n = 1014)	Clusters (n = 909)			
		Cluster 1 (n = 379)	Cluster 2 (n = 300)	Cluster 3 (n = 230)	*P-value*
Personal data					
Age					
Up to 40	359 (35.4)	135 (35.6)	120 (40)	81 (35.2)	0.652
Between 41 and 50	330 (32.5)	122 (32.2)	98 (32.7)	76 (33)	0.984
More than 50	325 (32.1)	122 (32.2)	82 (27.3)	73 (31.7)	0.716
Gender					
Female	503 (49.6)	123 (32.5)	157 (52.3)	169 (73.5)	**<0.001**
Male	511 (50.4)	256 (67.5)	143 (47.7)	61 (26.5)	
Education background					
Master, PhD or specialization	366 (36.3)	167 (44.2)	112 (37.7)	57 (24.8)	**<0.001**
University, college or equivalent	326 (32.3)	113 (29.9)	110 (37)	82 (35.7)	0.217
Professional	144 (14.3)	36 (9.5)	35 (11.8)	51 (22.2)	**<0.001**
Secondary school or less	167 (16.6)	62 (16.4)	38 (13.1)	40 (17.4)	0.530
Smoking status					
Never	576 (57.7)	238 (63.3)	174 (58.8)	116 (50.9)	0.112
Former	286 (28.6)	95 (25.3)	85 (28.7)	76 (33.3)	0.195
Current	136 (13.6)	43 (11.4)	37 (12.5)	36 (15.8)	0.500
Alcohol consumption					
Yes	804 (80.5)	318 (84.8)	231 (77.5)	181 (79)	0.079
Work-out (sport, gym and etc.)					
Average days per week	3 (1,5)	3 (1,4)	3 (2,5)	3 (1,5)	**0.038**
More than an hour per work-out session	249 (27.5)	111 (32.5)	68 (25)	47 (23)	0.057
Type of transportation for commuting					
Car	590 (58.2)	248 (65.4)	164 (54.7)	116 (50.4)	**<0.001**
Bike	451 (44.5)	146 (38.5)	151 (50.3)	116 (50.4)	**0.004**
Medical history (selected)					
Migraine	81 (8)	22 (5.8)	22 (7.3)	30 (13)	**0.011**
Asthma	93 (9.2)	30 (7.9)	28 (9.3)	27 (11.7)	0.479
Eczema	111 (10.9)	35 (9.2)	35 (11.6)	33 (14.3)	0.280
Allergy	229 (22.5)	88 (23.2)	51 (17)	69 (30)	**0.004**
High lipids in the blood (i.e. cholesterol, tryglicerids)	62 (6.1)	16 (4.2)	16 (5.3)	19 (8.3)	0.202
High blood pressure	111 (10.9)	34 (8.9)	31 (10.3)	27 (11.7)	0.790
Diabetes	25 (2.5)	8 (2.1)	8 (2.7)	4 (1.7)	0.943
Depression	38 (3.7)	10 (2.6)	11 (3.7)	13 (5.6)	0.301
Anxiety	16 (1.6)	4 (1)	5 (1.7)	7 (3)	0.348
Heart conditions	27 (2.6)	11 (2.9)	6 (2)	7 (3)	0.908
Other respiratory diseases	39 (3.8)	12 (3.1)	13 (4.3)	11 (4.7)	0.810
Psychiatric problems	26 (2.5)	11 (2.9)	5 (1.6)	7 (3)	0.755
None	483 (47.6)	190 (50.1)	160 (53.3)	90 (39.1)	**0.007**
Effort reward ratio (ERI)					
mean (SD)	0.46 (0.2)	0.41 (0.19)	0.50 (0.26)	0.47 (0.20)	**<0.001**

(*continued on next page*)

Table 6 (*continued*)

Characteristics	Total sample (n = 1014)	Clusters (n = 909)			
		Cluster 1 (n = 379)	Cluster 2 (n = 300)	Cluster 3 (n = 230)	*P-value*
Above 1	34 (3.3)	8 (2)	16 (5.4)	5 (2.3)	0.091
Over-commitment mean (SD)	12.8 (3.3)	12.6 (3.3)	13.2 (3.2)	12.6 (3.4)	0.067
Type of office					
Single private office	186 (18.4)	99 (26.2)	39 (13)	30 (13)	**<0.001**
Shared private office	356 (35.2)	184 (48.7)	84 (28.1)	58 (25.2)	**<0.001**
Open space with partition	91 (9)	22 (5.9)	33 (11)	28 (12.2)	**0.024**
Open space without partition	364 (36)	72 (19.3)	137 (47.8)	110 (49.5)	**<0.001**
Type of work					
Managerial	217 (21.4)	102 (26.9)	54 (18.1)	44 (19.1)	**0.021**
Professional	324 (32)	123 (32.5)	117 (39.1)	53 (23)	**<0.001**
Clerical-secretarial	251 (24.8)	76 (20.1)	62 (20.7)	84 (36.5)	**<0.001**
Others	220 (21.7)	78 (20.6)	66 (22.1)	49 (21.3)	0.989
Work-related					
Work with a VDU at work	991 (97.7)	358 (96.8)	295 (98.3)	227 (98.6)	0.418
Average hours per week with a VDU at work, mean (SD)	25.2 (10)	25.1 (10.4)	25.9 (9.8)	24.7 (9.3)	0.563
Average hours per week at your workstation, mean (SD)	28.5 (8.5)	28.7 (8.5)	28.5 (8.8)	28.6 (7.9)	0.913
Health symptoms (top 10)					
Dry eyes	312 (30.8)	50 (12.4)	92 (30.8)	140 (60.7)	**<0.001**
Dry skin	234 (23.1)	34 (8.9)	64 (21.4)	110 (48)	**<0.001**
Burning, irritated eyes	186 (18.3)	22 (5.7)	57 (19)	87 (38)	**<0.001**
Blocked, stuffy nose	176 (17.4)	34 (8.9)	49 (16.3)	72 (31.4)	**<0.001**
Headache	165 (16.3)	17 (4.6)	62 (20.7)	67 (29.3)	**<0.001**
Dry, irritated throat	160 (15.8)	19 (5.1)	51 (16.9)	72 (31.4)	**<0.001**
Sneezing	143 (14.1)	36 (9.5)	45 (14.9)	45 (19.7)	**<0.001**
Watering, itchy eyes	104 (10.3)	16 (4.1)	29 (9.8)	48 (21)	**<0.001**
Lethargy, unusual tiredness	83 (8.2)	7 (1.9)	32 (10.8)	30 (13.1)	**<0.001**
Runny nose	74 (7.3)	16 (4.1)	26 (8.5)	25 (10.9)	**<0.001**
IEQ-related complaints					
Overall noise quality	186 (18.3)	0 (0)	110 (36.7)	57 (24.8)	**<0.001**
Overall air quality	291 (28.7)	13 (3.4)	102 (34)	144 (62.6)	**<0.001**
Overall light quality	128 (12.6)	10 (2.6)	54 (18)	47 (20.4)	**<0.001**
Overall thermal quality	248 (24.5)	16 (4.2)	95 (31.7)	111 (48.3)	**<0.001**
Variation of temperature	208 (20.5)	15 (4)	90 (30)	70 (30.4)	**<0.001**
Cold temperature	209 (20.6)	34 (9)	91 (30.3)	57 (24.8)	**<0.001**
Hot temperature	129 (12.7)	22 (5.8)	38 (12.7)	59 (25.6)	**<0.001**
Draughty air movement	170 (16.8)	14 (3.7)	75 (25)	61 (26.5)	**<0.001**
Humid air	17 (1.7)	3 (0.8)	8 (2.7)	0 (0)	**0.026**
Dry air	548 (54)	106 (28)	159 (53)	230 (100)	**<0.001**
Stuffy air	254 (25)	31 (8.2)	83 (27.7)	106 (46.1)	**<0.001**
Smelly air	117 (11.5)	14 (3.7)	39 (13)	45 (19.6)	**<0.001**
Natural light	168 (16.6)	17 (4.5)	71 (23.7)	64 (27.8)	**<0.001**
Artificial light	144 (14.2)	10 (2.6)	61 (20.3)	55 (23.9)	**<0.001**
Reflection or glare	163 (16.1)	24 (6.3)	67 (22.3)	56 (24.3)	**<0.001**
Noise from outside	61 (6.0)	8 (2.1)	32 (10.8)	15 (6.5)	**<0.001**
Noise from building system	172 (17)	10 (2.7)	84 (28)	58 (25.2)	**<0.001**
Noise from inside	309 (30.5)	5 (1.3)	188 (62.7)	90 (39.1)	**<0.001**
Overall comfort	145 (14.3)	1 (0.3)	65 (21.6)	67 (29.3)	**<0.001**

P-values are from Bonferroni adjustments made after chi-square tests.

Table 7
Logistic regression analysis for association of symptoms for the three clusters of office workers.

Top 10 prevalent symptoms	Adjusted OR (95% CI)		
	Cluster 2	Cluster 3	
	vs. Cluster 1	vs. Cluster 1	vs. Cluster 2
Dry eyes	2.38 (1.56–3.64)***	8.06 (5.21–12.49)***	3.38 (2.31–4.96)***
Dry skin	2.06 (1.27–3.35)**	5.92 (3.67–9.55)***	2.87 (1.92–4.30)***
Burning, irritated eyes	3.23 (1.86–5.64)***	7.81 (4.50–13.55)***	2.42 (1.60–3.66)***
Blocked, stuffy nose	1.86 (1.12–3.06)*	4.60 (2.78–7.59)***	2.48 (1.60–3.84)***
Headache	4.3 (2.37–7.79)***	6.05 (3.31–11.09)***	NS
Dry, irritated throat	3.04 (1.70–5.44)***	6.42 (3.60–11.48)***	2.11 (1.37–3.27)***
Sneezing	NS	2.08 (1.23–3.54)**	NS
Watering, itchy eyes	2.08 (1.05–4.12)*	5.61 (2.89–10.9)***	2.70 (1.58–4.62)***
Lethargy, unusual tiredness	4.99 (2.10–11.82)***	5.79 (2.38–14.06)***	NS
Runny nose	2.10 (1.04–4.21)*	3.06 (1.50–6.34)**	NS

Note. Adjusted odds ratio implies controlling for gender, age, type of office and type of work.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, NS = not significant ($p > 0.05$).

health-related complaints and IEQ-dissatisfaction, respectively.

3.3.1. Description of clusters

3.3.1.1. Cluster 1: Healthy and satisfied workers

3.3.1.1.1. Personal characteristics. Cluster 1 represents 42% of the total sample (n = 909), and comprises of a high proportion of men (68%), more or less equally distributed among the different age groups. Most of the office workers are highly educated: 44% holds a degree that is equal or higher than a master degree. A significant number (65%) used

Table 8
Logistic regression analysis for association of IEQ dissatisfaction for the three clusters.

IEQ-related variables	Adjusted OR (95% CI)
	Cluster 3 (vs. Cluster 2)
Overall noise quality	0.51 (0.34–0.77)**
Overall air quality	3.3 (2.24–4.87)***
Overall light quality	NS
Overall thermal quality	1.83 (1.24–2.69)**
Variation of temperature	NS
Cold temperature	NS
Hot temperature	2.23 (1.40–3.59)***
Draughty air	NS
Humid air	NS
Dry air	21.05 (13.79–33.31)***
Stuffy air	3.21 (1.86–5.55)***
Smelly air	1.64 (1.01–2.67)*
Natural light	NS
Artificial light	NS
Reflection or glare	NS
Noise from outside	NS
Noise from building system	NS
Noise from inside	0.37 (0.25–0.54)***
Overall comfort	NS

Note. Adjusted odds ratio implies controlling for gender, age, type of office and type of work.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, NS = not significant ($p > 0.05$).

their own car for commuting to work. 50% of them reported to have at least one disease or problem. The most reported disease was 'allergy' (23%), followed by 'eczema' (9%) and 'high blood pressure' (9%).

3.3.1.1.2. IEQ-related complaints. Except for the fact that 28% of them described that their offices were 'too dry', generally very few (less than 10%) expressed clear dissatisfaction with the IEQ of their office. Almost none (0.3%) reported strong dissatisfaction with the overall comfort. As shown in Table 6, cluster 1 reported statistically significant less number of IEQ-related complaints compared to the other two clusters. The only exception was 'humid air', for which almost no one reported a complaint. Overall, the results suggest that the office workers grouped as cluster 1 were not bothered by the IEQ of their office environment.

3.3.1.1.3. Health symptoms. The most prevalent building-related symptom observed in this group was 'dry eyes' (12%). 10% frequently experienced 'sneezing' and 9% reported complaints about 'dry skin' and 'blocked, stuffy nose'. Except for 'sneezing' (no statistically significant difference between cluster 1 and cluster 2 was found), cluster 1 experienced building-related symptoms in the last 4 weeks significantly lower than the other profiles of the workers even after controlling for age, gender, type of office and type of work (see Table 7).

3.3.1.1.4. Work-related characteristics. The majority (75%) of cluster 1 worked in a (either single or shared) office, 50% of them answered that they shared their office with only one person (see Appendix A), and most reported type of work was 'professional' (33%). Compared to the average value of all the clusters, more 'managerial' (27% vs. 21%) and less 'clerical-secretarial' (20% vs. 25%) were observed. Almost all (97%) reported to work with a visual display unit (VDU) and average hours per week with a VDU at work was 25 h. Similar results were found in the other two clusters. Cluster 1 had the lowest mean ERI-value, which suggests that their work-related stress is perceived lower than in the other clusters.

3.3.1.1.5. Building and office characteristics. Cluster 1 respondents were most frequently located in small-sized office buildings (typical number of occupants <170: 70%; total floor area <1500 m^2: 43%), located in either industrial area or suburban or village in a rural area (51%), and most likely, therefore, exposed to relatively fewer sources of outdoor noise or air pollution than the office workers in the other clusters. The majority (80%) worked in offices with operable windows, carpet flooring (87%), mineral fibre ceiling tiles (84%) and dispersion, emulation paint on the wall (81%). Floors in their offices were cleaned at least once per week (72%) and almost no (6%) visible mould growth in their offices was spotted.

3.3.1.2. Cluster 2: Moderate healthy and noise-bothered workers

3.3.1.2.1. Personal characteristics. Cluster 2 represents 33% of the total sample and is balanced in terms of gender ratio (52% women and 47% men). This cluster tends to be younger (40% younger than 40) than the others and irrelevant to their educational background. Allergy (17%), eczema (12%) and high blood pressure (10%) were three most reported diseases. Car (55%) and bike (50%) were chosen most often for commuting to work.

3.3.1.2.2. IEQ-related complaints. This cluster had the highest percentage of noise complaints. 37% (vs. 18% total sample) were clearly dissatisfied with the overall noise quality and 63% (31% total sample) reported noise from inside (e.g. colleagues chatting or phone calls). A significant number of them also complained about IAQ. 34% were clearly dissatisfied with overall air quality, 53% with dry, 28% with stuffy and 25% with draughty air. Almost one-third complained about 'overall thermal comfort', 'too much variation of temperature' as well as 'too cold'. Light quality was least of their concerns: one-in-five were dissatisfied with their lit environment.

3.3.1.2.3. Health symptoms. 31% of this group experienced dry eyes symptoms more than once per week in the last month. Headache (21%), dry skin (21%) and burning, irritated eyes (19%) were reported. As can be seen in Table 7, except for 'sneezing' (15%), this group experienced a significantly higher number of health-related symptoms than Cluster 1. Interestingly, their average reported number of health-related symptoms are very close to the averages reported by the total sample (see Table 6).

3.3.1.2.4. Work-related characteristics. 48% of the respondents in Cluster 2 worked in an open space without partition; the number of occupants in the working space varied between 2 and 20 (median: 7). Compared to the average value of the total sample, a higher number of 'professionals' (39% vs. 32%) was seen compared to the total sample. Their average ERI score (and percentage of people who scored above an ERI of 1) was the highest among the three clusters, which suggests that this group seems to be under relatively high work-related stress.

3.3.1.2.5. Building and office characteristics. Cluster 2 respondents most frequently worked in large-sized buildings (typical number of occupants >170: 61%; total floor area >2500 m^2: 59%), located in the city centre (47%). For 97% of the buildings, sources of nearby outdoor noise and 99% outdoor air pollution were observed. A significant number of the respondents (39%) worked in buildings in which windows were not operable. Office covering and furnishing were found to significantly differ from the office environment of Cluster 1. A relatively higher number of them worked in offices which had synthetic smooth floor covering (27%), ceiling tiles (22%) and exposed concrete or plastered wall (17%). Although surfaces were cleaned at least once per week in 68% of the offices, in several of them (22%) visible mould growth was observed.

3.3.1.3. Cluster 3: Unhealthy and air and temperature-bothered workers

3.3.1.3.1. Personal characteristics. This cluster comprises of a high proportion of women (74%), while age is equally distributed over the three categories. With regards to their educational background, this group is different from the other two clusters; they consist of more 'professionals' and less workers with a 'master, PhD or specialization'. Also, they suffered from more diseases than the other clusters: workers suffering from 'allergy' (30%) and 'migraine' (13%) was found to be significantly higher. Apart from the above factors, workers in this cluster share very similar characteristics as the workers in Cluster 2.

3.3.1.3.2. IEQ-related complaints. This group in general complained a lot about IEQ. 63% of them were clearly dissatisfied with the 'overall

air quality' in their offices, 100% found the air 'too dry', 46% 'too stuffy', 27% 'too draughty' and 20% 'too smelly'. But also with the thermal conditions they were dissatisfied: 48% expressed clear dissatisfaction with overall thermal quality and 30% with 'temperature too variable', 25% found it 'too cold' and 26% 'too hot'. Acoustical quality was also a problem to them but not as much as Cluster 2 did. 39% reported 'too much noise from inside of their offices' and 25% were clearly dissatisfied with the 'overall noise quality'. The results presented in Table 8 show that this group was statistically significant more bothered by air-related factors and thermal-related factors, but less bothered by noise-related factors as compared to Cluster 2.

3.3.1.3.3. Health symptoms. In terms of health-related symptoms, this group can be described as the unhealthiest one. 61% and 48% experienced 'dry eyes' and 'dry skin' at least once per week in the last month, respectively. Multivariate logistic regression shows (Table 7) that - except for 'headache', 'sneezing', 'watering, itchy eyes' and 'lethargy, unusual tiredness'- this group reported the highest percentages of symptoms.

3.3.1.3.4. Work-related characteristics. Compared to the average values of the total sample, this cluster tends to work more in an open space without partition (50% vs. 36%) and less in a private office (38% vs. 54%). The number of occupants they are sharing their workspace with, varied from 3 to 25 (median: 8). There is a tendency that this group comprised more 'clerical-secretarial' (37% vs 22%) and less 'professional' (23% vs. 32%) workers, compared to the total sample.

3.3.1.3.5. Building and office characteristics. Cluster 3 workers are most frequently observed in large-sized buildings (typical number of occupants >170: 61%; total floor area >2500 m^2: 63%) located in the city centre (49%). Sources of outdoor noise (96%) and air pollution (99%) existed nearby the buildings. A significant number of workers in this cluster (44%) worked in buildings in which the windows were not operable. Office covering and furnishing were found to be significantly different from the typical office environment of Cluster 1 workers. A relatively higher number of them worked in offices with a synthetic smooth floor covering (18%), ceiling tiles (33%) and exposed concrete/plastered wall (11%). In 56% of the offices, the surfaces were cleaned at least once per week (56%) and in several of them (33%) visible mould growth was observed.

4. Discussion

4.1. Comparison to the European-wide OFFICAIR study

In this study, a clear gender effect on self-reported comfort and health from the office workers studied in the Netherlands was found. Compared to the European-wide OFFICAIR study [2,25,38] (see Fig. 3), the female workers in the Netherlands were generally more dissatisfied with their indoor environmental qualities, except for overall noise quality. For self-reported comfort, a gender effect was observed for both the European-wide OFFICAIR study and the OFFICAIR-study performed in the Netherlands. Unlike female workers, male workers in the Netherlands showed very similar patterns to the European-wide male workers.

Regarding building-related symptoms such as dry eyes and headaches, also a gender effect was observed in both the European-wide and the study in the Netherlands. Also, higher percentages of female workers in the Netherlands recorded complaints on dry eyes and headaches than female workers at European-wide level. For male workers, dry eyes were more reported in the Netherlands, while reported percentages of headache seemed almost the same.

It was also seen that open-plan offices were associated with higher numbers of comfort and health-related complaints than private offices. To check whether a consistent result was reported from the OFFICAIR (European-wide) study, a comparison of the results is made in Fig. 4. The results from both studies first suggest that open-plan offices were also associated with higher numbers of comfort and health-related complaints than private offices. But overall, open-plan offices in the Netherlands had much higher percentages of comfort and health-related complaints than open-plan offices from the European-wide study. Additionally, a significantly higher percentage of dry eyes complaints was reported by the occupants in private offices in the Netherlands, while there was almost no difference in percentages of dissatisfied workers with respect to their IEQ-factors as compared to the European-wide OFFICAIR study.

4.2. Comparison to other office building studies

The results of this study also confirm several findings from previous studies. De Dear et al. [39] observed significant gender differences in office environments for almost all IEQ factors (including thermal, air, lighting, acoustical quality, office layout, furnishings and cleanliness and maintenance), but not for the overall rating of their workspace environment. In this study, not only were females found to be consistently less satisfied with the indoor environmental conditions, including the overall comfort level of the offices, but females were also associated with a significantly higher number of most of the symptoms, particularly 'dry eyes', 'dry skin' and 'headache'. The result of this study shows that gender difference was particularly significant for overall thermal comfort, which confirms findings of previously published field research [39,44,45]. However, these gender effects can also be attributed to other factors such as differences in clothing and metabolic rate, which are often claimed to have an impact on the differences [45,46].

Further, the effect of office layout on self-reported health and comfort, which was found in this study, is in line with findings of several previous studies [47–49]. In this study, it was observed that office workers in open-plan layouts reported significantly higher numbers of 'headache', 'dry, irritated throat', 'dry eyes', and 'dry skin' symptoms as well as the fact that private single person offices clearly outperformed

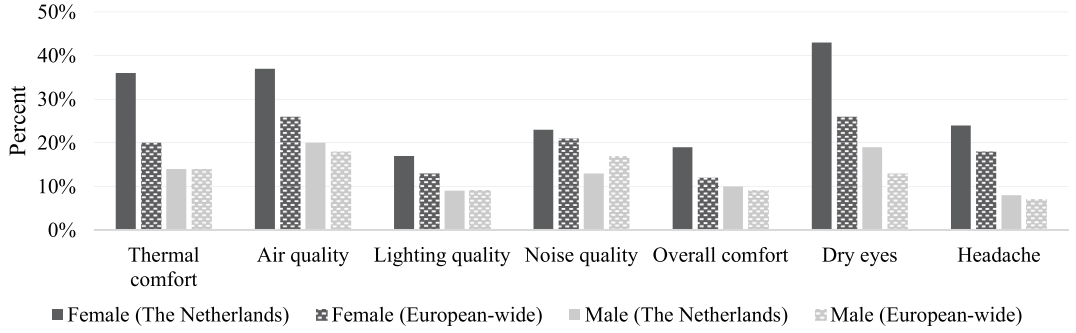

Fig. 3. The percentage of dissatisfied female/male occupants (subjects who rated their satisfaction level with the lowest 2 levels on the 7-point scale) for each of the IEQ-factors and the percentage of the occupants who experienced building-related symptoms at least once per a week in the last four weeks for both the European-wide OFFICAIR study and the OFFICAIR study in The Netherlands.

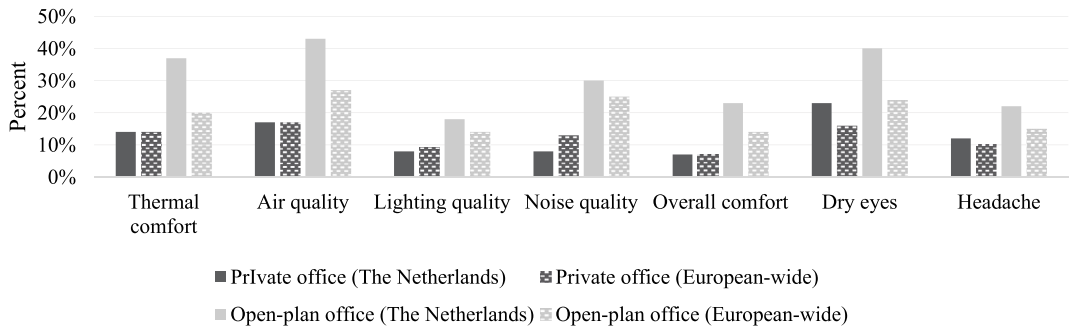

Fig. 4. The percentage of dissatisfied occupants at private office/open-plan office (subjects who rated their satisfaction level with the lowest 2 levels on the 7-point scale) for each IEQ factors and the percentage of the occupants who experienced dry eyes or headache at least once per a week in the past four weeks between the OFFICAIR (European-wide) and the OFFICAIR (The Netherlands).

open-plan layouts with respect to most IEQ-aspects. As Pejtersen et al. [49] summarized, these differences may be due to a) higher exposure to noise in open-plan office, b) differences in ventilation systems, c) exposure to viruses which presumably is higher in open-plan offices, d) differences in the psychosocial working environment, and e) presence of other humans when working which might lead to lower employee autonomy.

4.3. Strengths weaknesses and recommendations

This study is a first attempt to identify different profiles of office workers based on similarities in their IEQ-related complaints through the analysis of an existing dataset of the Dutch offices investigated in the OFFICAIR study. As a result, detailed descriptions of the profiles which include personal characteristics, life style, health symptoms, work characteristics and building/office characteristics were provided. The results have shown particularly large differences between profiles with regard to their health symptoms at work.

To validate the findings better, further studies are recommended as the current study includes a few limitations. First, since the profiles of office workers in this study were created mainly through analysis of self-reported *complaints*, it would be beneficial to include additional information such as user preference, needs and control behaviours for further studies when designing their data gathering stage. In particular, as several recent studies [35–37] have shown that users' *needs* and *preferences* were key determining items for their final models of school children and home occupant archetypes, it is expected that such data also is important for enhancing our understanding of the profile of office workers when included.

Additionally, based on the findings of this study, a few recommendations can be made to architects, facility managers and researchers who are keen on designing (or achieving) a healthy office environment. The study suggests different individual specific and context-relevant priorities for different profiles of office occupants rather than devising a fit-for-all solution. For example, providing acoustical privacy panels to the moderately healthy and bothered by noise group is likely to result in a decrease in IEQ-related complains, whereas the same approach might not be so effective to other profiles. Secondly, there is a need for further human-oriented research to better understand the different office workers. In particular *the moderate healthy and noise-bothered workers* and *unhealthy and air and temperature-bothered workers* for whom their work characteristics and office/building characteristics didn't differ so much. For example, quantifying and assessment of exposure to different air quality, acoustical and lighting condition for longer period at a *personal level* would be desirable.

5. Conclusion

In conclusion, this study raised a particular concern for female workers and open-plan offices in the Netherlands, as their self-reported comfort and health were in general much worse than the average scores from the European-wide OFFICAIR study. Then, three different profiles of office workers in the Netherlands based on their self-reported health and comfort were identified using a large database that consisted of both office workers' comfort and health reports and characteristics of their office buildings. The results indicate that office workers can be grouped into the ones who are *satisfied* with their indoor environments, the ones who *complain about indoor noise*, and the ones who are *bothered by indoor air and temperature*. While the satisfied workers were by far the healthiest among the groups, significantly higher health risks were identified for the office workers who complained about indoor air and temperature than the ones who were bothered most by indoor noise. As the outcome confirmed, there is a need of 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* in order to be able to provide customized solutions for their complaints.

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.

Acknowledgement

This study was sponsored by the fellowship of Philomena Bluyssen provided by the Delft University of Technology under the chair of Indoor Environment.

Appendix. Building and office characteristics

Table A.1
Building characteristics and indoor conditions for the three profiles of office workers.

Building and office characteristics	Cluster 1	Cluster 2	Cluster 3	P-value
Building location				
Industrial area	79 (20.8)	17 (5.7)	19 (8.3)	<**0.001**
Mixed industrial/residential area	68 (17.9)	58 (19.3)	39 (17)	0.949
Commercial area	37 (9.8)	10 (3.3)	11 (4.8)	**0.003**
Mixed commercial/residential area	58 (15.3)	22 (7.3)	15 (6.5)	<**0.001**
City centre, densely packed housing	50 (13.2)	140 (46.7)	113 (49.1)	<**0.001**
Suburban, with large gardens or village in a rural area	87 (29.9)	53 (19)	33 (15.6)	**0.048**
Typical number of occupants (building)				
Up to 70	83 (21.9)	33 (11)	37 (16.1)	**0.002**
Between 71 and 170	181 (47.8)	85 (28.3)	53 (23)	<**0.001**
More than 170	115 (30.3)	182 (60.7)	140 (60.9)	<**0.001**
Total floor area				
Up to 1500m^2	163 (43)	59 (19.7)	50 (21.8)	<**0.001**
Between 1501m^2 to 2500m^2	80 (21.1)	65 (21.6)	35 (15.2)	0.240
More than 2500m^2	136 (35.8)	176 (58.7)	145 (63)	<**0.001**
[1]Number of occupants in the workstation (incl. yourself)	2 (1–6)	7 (2–20)	8 (3–25)	<**0.001**
Acoustics				
Outdoor source of noise (within 100 m)				
Yes	341 (90)	291 (97)	221 (96)	<**0.001**
No	38 (10)	9 (3)	9 (4)	
Indoor source of noise				
Yes	203 (53.6)	209 (69.7)	168 (73)	<**0.001**
No	176 (46.4)	91 (30.3)	132 (27)	
Acoustical solutions: insulation and/or sound absorption				
Yes	203 (53.6)	298 (69.7)	168 (73)	<**0.001**
No	176 (46.4)	91 (30.3)	62 (27)	
Lighting				
Solar shading devices				
No	0 (0)	0 (0)	0 (0)	
Yes, no control (fixed)	0 (0)	0 (0)	0 (0)	
Yes, automatic control	82 (21.6)	72 (24)	40 (17.4)	0.329
Yes, manual control	270 (71.2)	223 (74.3)	180 (78.3)	0.291
Control of main lights (e.g. ceiling or wall)				
Manual	283 (74.7)	203 (67.7)	185 (80.4)	**0.007**
Automatic with manual end control	23 (6)	20 (6.7)	4 (1.7)	**0.046**
Fully automatic	73 (19.3)	77 (25.7)	41 (17.8)	0.096
Ventilation				
Outdoor source of air pollution (within 100 m)				
Yes	353 (93.1)	296 (98.7)	227 (98.7)	<**0.001**
No	26 (6.9)	4 (1.3)	3 (1.3)	
Type of ventilation				
Mechanical ventilation	372 (98.2)	294 (98)	230 (100)	0.49
Balanced system with induction	73 (19.2)	18 (6)	24 (10.4)	<**0.001**
Balanced system with CAV	103 (27.2)	95 (31.7)	96 (41.7)	**0.002**
Balanced system with dual ducts	95 (25)	49 (16.3)	19 (8.3)	<**0.001**
Balanced system with VAV	80 (21.1)	65 (21.7)	53 (23.0)	0.978
Hybrid/mixed mode	7 (1.8)	6 (2)	0 (0)	0.49
Control of mechanical ventilation				
Central-clock	238 (62.8)	98 (32.7)	66 (28.7)	<**0.001**
Central-demand	123 (32.5)	152 (50.7)	138 (60)	<**0.001**
Designed air distribution principle				
Mixing	340 (89.7)	260 (86.7)	209 (90.9)	0.454
Displacement	39 (10.3)	40 (13.3)	21 (9.1)	
Relative humidity controlled by the system				
Yes, set point is 45–50	45 (11.9)	87 (29)	79 (34.3)	<**0.001**
Yes, set point is 38–40	39 (10.3)	7 (2.3)	8 (3.5)	<**0.001**
Yes, set point is 30	56 (14.8)	17 (5.7)	10 (4.3)	<**0.001**
No	239 (63.1)	189 (63)	133 (57.8)	0.754
Humidification in mechanically ventilated buildings				
Yes	150 (39.5)	157 (52.3)	118 (51.3)	**0.002**
No	329 (60.5)	143 (47.7)	112 (48.7)	
Air handling unit (AHU)				
100% fresh air AHU	297 (78.4)	262 (87.3)	191 (83)	**0.018**
AHU with recirculating	82 (21.6)	38 (12.7)	39 (17)	
Openable windows				
Yes	303 (80)	151 (50.3)	99 (43)	<**0.001**
Yes, but occupants not allowed to open them	36 (9.5)	32 (10.7)	30 (13)	0.63
No	40 (10.6)	117 (39)	101 (43.9)	<**0.001**
Heating and cooling				

(*continued on next page*)

Table A.1 (*continued*)

Building and office characteristics	Cluster 1	Cluster 2	Cluster 3	P-value
Non-electric heaters (for heating and/or water)				
None	323 (85.2)	316 (83.3)	338 (89.1)	0.301
Outside building	17 (5.5)	13 (4.3)	5 (1.7)	0.144
Inside building	21 (9.2)	29 (12.3)	21 (9.1)	0.565
Cooling system				
Package air cooled chiller	58 (15.3)	27 (7)	36 (9.6)	**0.004**
Water cooled chiller + cooling tower	160 (53.3)	155 (51.7)	123 (40.9)	**0.016**
Heat pump	17 (7.4)	24 (10.3)	20 (8.7)	0.640
Air condensed water chiller	22 (5.8)	67 (22.3)	75 (32.6)	<**0.001**
Control of the room temperature				
Local thermostats at radiator/heating unit	82 (21.6)	21 (7)	23 (10)	<**0.001**
Local thermostats (e.g. on wall)	209 (55.1)	177 (59)	110 (47.8)	0.104
Other manual control	51 (13.4)	84 (28)	84 (36.5)	<**0.001**
Central sensor	21 (5.5)	9 (3)	4 (1.7)	0.116
Zone sensor	6 (1.8)	3 (1)	4 (1.7)	0.956
Set room temperature of the building (during winter)				
20	47 (12.4)	15 (5)	11 (4.7)	<**0.001**
21	212 (55.9)	139 (46.3)	120 (52.2)	0.129
22	77 (20.3)	47 (15.7)	40 (17.4)	0.629
23	7 (1.8)	22 (7.3)	16 (7)	**0.004**
Office covering, furnishings				
Main type of wall covering in the offices				
Exposed concrete/plaster	18 (4.7)	50 (16.7)	26 (11.3)	<**0.001**
Dispersion, emulsion paint	305 (80.5)	212 (70.7)	190 (82.6)	**0.002**
Wall paper	44 (11.6)	33 (11)	8 (3.5)	<**0.001**
Main type of floor covering in the offices		)		
Carpet	329 (86.8)	214 (71.3)	183 (79.6)	<**0.001**
Synthetic smooth	38 (10)	81 (27)	41 (17.8)	<**0.001**
Main type of ceiling covering in the offices				
Exposed concrete/plaster	17 (4.5)	52 (17.3)	22 (9.6)	<**0.001**
Mineral fibre tiles	319 (84.2)	168 (56)	129 (56.1)	<**0.001**
Printer/copy machines location in general				
In the offices	12 (3.2)	5 (1.7)	6 (2.6)	0.713
In a separate printing room	103 (27.2)	105 (35)	115 (50)	<**0.001**
On the corridor	264 (69.7)	1190 (63.3)	110 (47.4)	<**0.001**
Maintenance of the building				
Cleaning activities				
Surface cleaned in the offices at least once per week,				
Yes	273 (72)	204 (68)	129 (56.1)	<**0.001**
No	106 (28)	96 (32)	101 (44.9)	
Office cleaned generally				
In the morning	100 (26.3)	24 (8)	20 (8.7)	<**0.001**
During working hours	292 (60.5)	240 (80)	175 (76.1)	**0.022**
In the evening after work	50 (13.2)	36 (12)	35 (15.2)	0.802
Signs of humidity				
Visible mould growth in the offices				
Yes	22 (5.8)	67 (22.3)	75 (32.6)	<**0.001**
No	357 (94.2)	233 (77.7)	155 (67.4)	
Damp spots on the walls, ceilings or floors				
Yes	46 (12.1)	41 (13.7)	32 (13.9)	
No	333 (87.9)	259 (86.3)	198 (86.1)	0.946
Others				
A documented complaints procedure for occupants with problems of the indoor environment				
Yes	313 (82.6)	261 (87)	211 (91.7)	**0.011**
No	66 (17.4)	39 (13)	19 (8.3)	
Smoking in the building				
Only in a separately ventilated room	199 (52.5)	204 (68)	167 (72.6)	<**0.001**
Smoking is prohibited in the building	180 (47.5)	96 (32)	63 (27.4)	

[1]The data is reported as median (interquartile range (IQR) as a range).

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