Gender differences in office occupant perception of indoor environmental quality (IEQ)

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Abstract

This paper investigates the gender differences in the occupants' perception on various aspects of indoor environmental quality (IEQ) by two lines of inquiry; Firstly, a comprehensive literature survey spanning the research areas of indoor air quality (IAQ), sick building syndrome (SBS), thermal comfort, lighting, and acoustics was conducted. Secondly, statistical analyses were performed on a large, predominantly North American Post-Occupancy Evaluation (POE) database (N=38,257). Statistical analyses indicated that female occupants' satisfaction levels were consistently lower than male occupants for all fifteen IEQ factors (including thermal comfort, air quality, lighting, acoustics, office layout & furnishings, and cleanliness & maintenance) addressed in POE questionnaire, and the differences were statistically significant. Logistic regression analysis identified a significant association between female gender and dissatisfaction with individual IEQ factors. Those gender differences quantified by odds ratios (OR) were most pronounced for dissatisfaction with thermal environment, IAQ, and workspace cleanliness. The analyses produced consistent results, even after potential confounding factors such as age and work characteristics were controlled.

Keywords

Indoor environmental quality, gender difference, satisfaction, office building, thermal comfort, indoor air quality

1. Introduction

For several decades, there has been research interest in how the conditions of indoor environment affect the office workers' performance, health, or satisfaction [e.g. 1-3]. Providing optimal, or at least comfortable environment that can satisfy a majority of occupants is deemed to be important, and has

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been the primary goal of conventional facilities management practice, particularly in the context of commercial office environments in which individual occupant's control over their surrounding environments is usually restricted. However, indoor environments deemed satisfactory by a certain occupant group may not be satisfactory to another. Building occupants often react in noticeably different ways under the same indoor environment, leading to a presumption that various personal or psychosocial factors beyond environmental parameters influence occupants' perception of the quality of indoor environment [e.g. 4-6].

Conducting an occupant survey is the most prevalent method of data collection that can be found in post-occupancy evaluation (POE) researches across diverse disciplines, including psychology, the social, health, and building sciences [e.g. 7-10]. Common to all of them though is the goal of understanding causal relationships between indoor environment and the behaviour, perception and comfort of building occupants. Those surveys often (perhaps in most cases) collect the respondents' gender information. However, not all of them report the result based on the gender differences. In fact, despite a very large number of indoor environment surveys, only a few specifically address the gender effect. Some debates on the gender difference can be found in Sick Building Syndrome (SBS) or thermal comfort studies [e.g. 11-14] but the results are scattered and there is still ambiguity. A recent review paper focused specifically on gender differences in the thermal comfort literature noted that females were, on average, 74% more likely to express thermal dissatisfaction than males [15], prompting this wider enquiry into gender differences across all IEQ domains.

The primary objective of this paper is to investigate gender differences in the occupants' perception of all IEQ issues. Firstly, a literature survey is conducted to synthesise information about gender effects reported in the previous research literature on different IEQ dimensions, including IAQ (indoor air quality)/SBS, thermal comfort, acoustics, and lighting. Secondly, a detailed statistical analysis is conducted on a large occupant survey database (POE) from the Center for the Built Environment (CBE) at the University of California, Berkeley, focusing on how female and male occupants respond to the various aspects of office indoor environments. Then our discussion section is developed by comparing findings from the literature survey and the statistical analysis on the POE database.

2. Literature survey

Table 1 summarises the literature that investigated gender differences within the context of IEQ. Studies that didn't clearly address the statistical significance of gender differences were not included in this survey. A total of 35 published research articles were included in Table 1 and a majority of those were field studies based on questionnaire survey with or without simultaneous instrumental measurements of IEQ parameters, but some were based on the controlled environmental chamber research method. The characteristics of the study population were diverse in terms of sample sizes,

Table 1. Summary of previous IEQ researches that investigated gender differences

Study	Population	Method	Main scope	Data analysis	Results	Specific factors investigated for gender difference	Gender difference
Aries et al. (2010) [16]	N=333 (140 females and 193 males) from 10 office buildings in Netherlands	Questionnaire survey	Office layout, Lighting, SBS	Multiple regression	The relationship between gender and light quality (e.g. office lighting and desk lighting; ß=-0.14), physical & psychological discomfort (e.g. concentration problem, dullness, headache, bad vision, and dry throat/eyes; ß=0.19) was identified	Light quality	YES
						Physical and psychological discomfort (SBS symptoms)	YES
Bakke et al. (2007) [17]	N=173 (92 females and 81 males) from 4 university buildings	Questionnaire, Blood sample, Objective measurement of IEQ parameters	Thermal, IAQ	*t*-test Linear/Logistic regression	Indoor air symptoms (e.g. fatigue, concentration difficulties, eye irritation, dry throat and cough) were reported more often among females than males (p<0.05). Females had more frequent IEQ complaints (e.g. draft, temperature too high/low, stuffy/dry air, odour, and inadequate lighting; p<0.05).	Indoor air symptoms (SBS symptoms)	YES
						IEQ complaints	YES
Baron et al. (1992) [18]	N=92 (27 females and 64 males)	Laboratory-setting experiment	Lighting	ANOVA, MANOVA	No gender differences observed in relation to the effects of indoor lighting on cognitive task performance	Indoor lighting (Illuminance and spectral distribution)	NO
Becker and Paciuk (2009) [19]	N=394 (52% female) from residential buildings in Haifa, Israel	Questionnaire survey, Objective measurement of indoor thermal environment	Thermal	Linear regression, Comparison of PMV and actual thermal sensation vote	Thermal sensation corresponding to the operative temperature wasn't significantly different between the two sexes.	Thermal sensation	NO
Beshir and Ramsey (1981) [20]	N=46 (15 females and 31 males)	Laboratory-setting experiment	Thermal	Linear regression	Neutral temperature (WBGT) was higher for females (22°C) compared to males (25°C). Female subjects reported higher levels of drowsiness and boredom, while male subjects reported higher fatigue.	Thermal sensation, drowsiness, boredom, and fatigue	YES
Brasche et al. (2001) [21]	N=1,464 (888 females and 576 males) from 14 office buildings in Germany	Questionnaire survey	SBS	Logistic regression, Chi-square test	Higher prevalence of SBS was reported for females (44.3%) than males (26.2%). SBS complaints were significantly higher for females (Odd Ratio=2.1)	Sick Building Syndrome (SBS) symptoms	YES
Burge et al. (1987) [22]	N=4,373 from 42 office buildings in UK	Questionnaire survey	SBS	ANOVA	Females reported significantly more SBS symptoms (mean building sickness index) than males (p<0.001)	Sick Building Syndrome (SBS) symptoms	YES
Cena and de Dear (1999) [11]	N=1,229 responses (935 subjects; 48% female) from 22 office buildings in Kalgoorlie-Boulder, Australia	Questionnaire survey, Objective measurement of indoor thermal environment	Thermal	Calculation of thermal comfort indices, Linear/Probit regression	Females reported significantly higher thermal dissatisfaction (votes of thermally unacceptable) than males (p<0.01).	Thermal acceptability (dissatisfaction)	YES
Choi et al. (2010) [23]	N=402 (212 females and 190 males) from 20 office buildings in US	Questionnaire survey, Objective measurement of indoor thermal environment	Thermal	*t*-test ANOVA	Females reported significantly lower satisfaction level with indoor thermal condition (p=0.000)	Thermal dissatisfaction	YES
de Dear and Fountain (1994) [24]	N=1,234 responses (836 subjects; 58% female) from 12 office buildings in Townsville, Australia	Questionnaire survey, Objective measurement of indoor thermal environment	Thermal	Calculation of thermal comfort indices, Linear/Probit regression, Chi-square test	There were no significant differences in thermal neutralities between the sexes (males=24.2°C, females=24.3°C). Females expressed significantly higher thermal dissatisfaction (68% female; 32% male; Chi^2= 12.9, p<0.005)	Thermal neutrality	NO
						Thermal acceptability (dissatisfaction)	YES
Donnini et al. (1997) [12]	N=877 (50% female) from 12 office buildings in Quebec, Canada	Questionnaire survey, Objective measurement of indoor thermal environment	Thermal	Calculation of thermal comfort indices, Linear/Probit regression, Chi-square test	There were no significant differences in thermal neutralities between the sexes (males=23.5°C, females=23.8°C). Females expressed significantly higher thermal dissatisfaction (63% female; 37% male; Chi^2=8.9, p<0.003)	Thermal neutrality	NO
						Thermal acceptability (dissatisfaction)	YES
Ellermeier and Zimmer (1997) [25]	N=72 (41 females and 31 males)	Laboratory-setting experiment	Acoustics	Correlation ANOVA	Individual performance decrements due to irrelevant noise weren't significantly different between the sexes.	Noise sensitivity (susceptibility to irrelevant speech)	NO

Golja et al. (2003) [26]	N=10 (5 females and 5 males)	Laboratory-setting experiment	Thermal	ANOVA	Forearm skin temperature just noticeable differences for cold (p<0.05) and warm sensation (p<0.005) were significantly smaller for females compared to males.	Thermo-sensitivity	YES
Grivel and Candas (1991) [27]	N=48 (24 females and 24 males)	Laboratory-setting experiment	Thermal	ANOVA	The mean of preferred temperature (the subjects were asked to adjust the ambient temperature to the levels they preferred) was 0.5°C higher for females than males but the difference was not significant.	Preferred temperature	NO
Indraganti and Rao (2010) [28]	N=3,962 responses (113 subjects; 65% female) from 45 apartments in India	Questionnaire survey, Objective measurement of IEQ	Thermal	Correlation	Thermal sensation and gender was significantly correlated (at 5% level) but the relationship was very weak (r = -0.08). Women showed a slightly higher thermal acceptability (88%) than men (83%).	Thermal sensation	NO
Karjalainen (2007) [29]	N=3,094 (1,556 females and 1,538 males) for home environment; N=1,000 (520 females and 480 males) for office environment	Interview survey by telephone	Thermal	Mann-Whitney, Chi-square	Men reported higher satisfaction levels with temperature in general. Percentage of uncomfortably hot or cold votes was consistently higher for females.	Thermal satisfaction	YES
Kinman and Griffin (2008) [30]	N=346 (55% female) from 5 office buildings	Questionnaire survey	SBS	ANOVA, Correlation, Hierarchical multiple regression	No gender differences were observed in the self-reported SBS symptoms	Sick Building Syndrome (SBS) symptoms	NO
Klitzman and Stellman (1989) [8]	N=1,830 office workers (1,334 females and 496 males) in US and Canada	Questionnaire survey	IAQ, Lighting, Acoustics, Ergonomics, Privacy	Factor analysis, Correlation, Stepwise multiple regression	The association between gender and psychological well-being was insignificant (Job satisfaction, office satisfaction, and irritation) or small (Fatigue ß=-0.13, p<0.01; generalised distress ß=-0.09, p<0.05), whereas air quality and noise were the strongest predictors of psychological well-being	Job satisfaction, office satisfaction, and irritation	NO
						Fatigue and generalised distress	YES
Knez and Enmarker (1998) [31]	N=80 (50% female)	Laboratory-setting experiment	Lighting	ANOVA	There were significant gender differences (or interaction between gender and colour temperature) in the evaluation of office lighting condition.	Office lighting (glaring, dim, soft, bright, warm, intense, and cool)	YES
Laike and Tonello (2009) [32]	N=206 (65 females and 141 males) from office buildings in Argentina and Sweden	Questionnaire survey, Objective measurement of IEQ	Thermal, Lighting, Acoustics, SBS	Multiple regression	Gender was identified as an insignificant predictor for SBS symptoms	Sick Building Syndrome (SBS) symptoms	NO
Nakano et al. (2002) [33]	N=406 office workers (184 females and 222 males)	Questionnaire survey, Objective measurement of IAQ and thermal environment	IAQ, Thermal, SBS	Linear regression	Significant differences (p<0.05) in neutral temperature was found between females (25.1°C) and males (22.9°C). Japanese female group reported higher frequency of SBS symptoms compared to male groups.	Neutral temperature	YES
						Sick Building Syndrome (SBS) symptoms	YES
Norbäck and Edling (1991) [34]	N=466 residents in Sweden (51% female)	Questionnaire survey	SBS	Logistic/linear regression	Females reported higher prevalence of SBS symptoms than males but the differences were not significant when controlling for other factors (allergy to nickel, hyperreactivity and proneness to infection)	Sick Building Syndrome (SBS) symptoms	NO
Parsons (2002) [35]	N=32 (16 females and 16 males)	Laboratory-setting experiment	Thermal	Comparison between PMV and AMV	Female subjects felt cooler (AMV = close to -2) than males (AMV = close to -1) in a cool condition (18.5°C, PMV = -2), whereas no gender differences were observed when PMV range was between -1.5 and +1.5	Thermal sensation in a cool condition	YES
Pellerin and Candas (2003) [36]	N=108 (54 females and 54 males)	Laboratory-setting experiment	Thermal, Acoustics	ANOVA	Significant interaction (p<0.05) between sex and experiment protocol (change in temperature and noise level) was found. Females chose noisier but close-to-neutral thermal condition compared to males.	Combined effect of noise and temperature	YES
Reynolds et al. (2001) [37]	N=368 (282 females and 86 males) from 6 office buildings in US	Questionnaire survey, Objective measurement of IEQ	IAQ	t-test, Chi-square, Correlation	Psychosocial factors were significantly related to increased numbers of SBS symptoms in females, while environmental factors were correlated with symptoms in males.	Factors associated with SBS symptoms	YES
Rohles (1979) [38]	N=108 (50% female)	Laboratory-setting experiment	Thermal	ANOVA	There was no significant difference in neutral temperature between the sexes.	Neutral temperature	NO
Schellen et al. (2013) [39]	N=20 (10 females and 10 males)	Laboratory-setting experiment	Thermal	Calculation of thermal comfort indices,	Female subjects' mean thermal sensation vote was significantly lower than males (p<0.05). Females felt more uncomfortable than males	Thermal sensation	YES

				ANOVA, Correlation	(p<0.05). Correlation between whole-body thermal sensation and local thermal sensation was found for female subjects.	Thermal comfort (dissatisfaction)	YES
						Effect of local thermal sensation	YES
Skov et al. (1989) [40]	N=3,507 (2,347 females and 1,115 males) mainly from public buildings in Denmark	Questionnaire survey	SBS	Logistic regression	Females had a higher prevalence of work-related mucosal irritation and general symptoms than males.	SBS symptoms (work-related mucosal irritation and general symptoms)	YES
Stenberg and Wall (1995) [13]	N=4,943 (53% female) office workers in Sweden	Questionnaire survey	SBS	Logistic regression	The prevalence of SBS was higher among females than males. Odd Ratio for SBS was 3.4 among females	Sick Building Syndrome (SBS) symptoms	YES
Veitch and Newsham (2000) [41]	N=94 (52 females and 42 males)	Laboratory-setting experiment	Lighting	MANOVA	Gender did not significantly influence lighting choices.	Lighting preferences	NO
Wolkoff (2008) [42]	N/A	Literature survey	Thermal, IAQ	Literature survey	Epidemiological studies reported that females have higher prevalence of eye symptomatology under office environment	Eye irritation symptoms	YES
Yang et al. (2012) [43]	N=91 (53 females and 38 males) students in China	Laboratory-setting experiment	Acoustics	ANOVA	Three-way significant interaction among background noise, cognitive task performance and gender was identified.	Noise distraction	YES
Yildirim et al. (2007) [44]	N=41 (17 females and 24 males) from an office building in Turkey	Questionnaire survey	Office layout	ANOVA	Female occupants evaluated the office environment more negatively (p<0.01) compared to males in open-plan offices.	Perceived environmental conditions of office planning, privacy and lighting	YES
Zalejska-Jonsson and Wilhelmsson (2013) [45]	N=5,660 (53% female) from residential buildings in Sweden	Questionnaire survey	Thermal, IAQ, Acoustics	Logistic regression	Effect of thermal comfort on overall evaluation of IEQ is greater among female occupants than male occupants. Problems with IEQ (stuffy air, draught, and dust) have a greater effect on females than males.	Thermal comfort and problems with IEQ influencing overall IEQ satisfaction	YES
Zweers et al. (1992) [14]	N=7,043 (65% female) from 61 office buildings in Netherlands	Questionnaire survey, Objective measurement of IAQ and thermal environment	IAQ (SBS), Thermal	Logistic regression	Gender was associated with an increased prevalence of SBS symptoms (e.g. skin/eye/oronasal symptoms) and indoor climate complaints (e.g. temperature, air quality, lighting, noise, and dry air).	Health symptoms and IEQ complaints	YES

location and occupancy (office, residential, and controlled environmental chamber). The samples come from different continents including North and South America, Asia, Middle East, Europe, and Oceania, and sample sizes varied from 41 up to 7,043 for the field studies, and 20 to 94 for the laboratory experiments. Most occupant samples in the field studies reflect office workforces, but some were based on residential samples. Among the four main dimensions of IEQ, notably IAQ (including SBS), thermal comfort, lighting and acoustics, the literature was dominated by IAQ/SBS and thermal comfort studies.

The studies that associated occupants' common health symptoms with the indoor environment (particularly with IAQ) typically found women reporting higher prevalence of those symptoms. Eleven out of fourteen IAQ/SBS research projects in our literature survey reported women as more likely than men to suffer from SBS symptoms such as fatigue, headache, irritated or dry eyes/nose/throat, and skin symptoms. In these studies, logistic regression was the usual data analytic approach, treating gender as the predictor of SBS symptom prevalence. The likelihood of having SBS symptoms quantified by odds ratio (OR) was higher among females than males [13, 21, 40, 46]. While a majority of the studies we reviewed identified gender as a significant predictor of SBS symptom prevalence, there were some contradictory findings as well. Kinman and Griffin [30] suggested that men and women who work under comparable workplace social conditions reported similar levels of SBS symptoms, implicating psychosocial factors in gender differences for SBS symptom prevalence. Norbäck and Edling [34] argued that, although women had a higher proportion of SBS symptoms than men, these differences were not significant when intervening variables, including allergy to nickel, hyperreactivity and proneness to infection were controlled.

More extensive debates of the gender effect can be found within thermal comfort literature. Factors such as thermal sensation (or neutrality[1]) and thermal acceptability (or dissatisfaction) have been explicitly addressed. A field research conducted in Japan identified significant differences in thermo-neutrality between the two sexes [33], in which the female group registered significantly higher neutral temperature (25.1°C) compared to the male group (22.9°C). An experimental study on a small sample by Beshir and Ramsey [20] reported preferred temperatures for females significantly higher than those for males. Based on this result they suggested that workspace set-point temperatures need to be slightly higher for predominantly female workforces. When exposed to a cool condition, female subjects felt cooler than males; under the identical thermal condition, females' mean thermal sensation votes (AMV) was close to -2 (i.e. "cool" in the seven-point thermal sensation scale), while males' AMV was close to -1 (i.e. "slightly cool") [35]. Golja et al. [26] observed just noticeable skin temperature thresholds by directly stimulating subjects' forearms. Their experimental study

[1] Neutral temperature or neutrality is defined as the operative temperature within the occupied zone corresponding with an average vote of "neutral" on the thermal sensation scale.

demonstrated that females had a significantly smaller skin temperature threshold for cool sensations to be noticed (0.3K and 0.7K cooler than adapted temperature for female and male subjects respectively). Likewise on the warm side, females reported warm sensations when skin temperature rose 0.7K above adapted temperature, compared to 1.2K for male subjects. These findings led Golja et al. [26] to conclude that women are more sensitive to cold and warm conditions than men. Pellerin and Candas [36] investigated the combined effect of thermal and acoustical environments on discomfort. Under a trade-off condition between temperature and noise, female subjects chose the noisier environment but close-to-neutral thermal environment, showing a stronger tendency to remain closer to thermo-neutral conditions than males. On the other hand, there exist studies contradicting these findings. A field study conducted in residential buildings failed to observe a gender difference in the occupants' thermal sensation corresponding to the operative temperature [19]. Also, several climate chamber experiments demonstrated that the gender effect was not significant in terms of ambient temperature corresponding to thermal neutrality or preference [27, 38]. A series of ASHRAE-sponsored field experiments of occupant comfort and office thermal environment were carried out in diverse climate zones [11, 12, 24]. They consistently reported no gender differences in thermal neutrality, but significantly more frequent expressions of thermal dissatisfaction from females than males were observed, despite comparable indoor thermal environmental conditions. A more recent POE research also reported the same observation [23]. According to Table 1, gender differences in thermal sensation or neutrality observed in laboratory experiments are not universally consistent. However, most of the field studies based on relatively large samples (~1,000) consistently reported females as being more dissatisfied with indoor thermal environments than males.

A few research articles were also found within the scope of indoor lighting and acoustics (noise). The relationship between gender and light quality (satisfaction with office lighting and task lighting) was identified in the field study by Aries et al. [16]. Knez and Enmarker [31] reported that lighting was perceived significantly differently by females compared to males, but gender was unrelated to lighting preferences [41] or the effects of lighting on cognitive task performance [18]. In open-plan offices, environmental conditions such as office layout planning, privacy and lighting were evaluated more negatively by female workers compared to males [44]. In studies exploring distraction by noise, Ellermeier and Zimmer [25] reported noise sensitivity quantified by individual performance decrements due to irrelevant noise weren't significantly different between the sexes, whereas Yang et al. [43] did find significant interactions between noise, task performance and gender.

The literature survey summarised in Table 1 suggests that there are debates between researchers on whether gender effects on the occupants' perception of IEQ exist or not. Although SBS and thermal comfort studies generally agree that gender differences exist, the ambiguity in the research literature to date warrants further investigation in a very large field database.

3. Methods

3.1 Occupant survey database

Although the influence of the office environment on occupants has attracted inter-disciplinary research attention over recent decades, the literature remains incoherent and ambiguous. This is possibly the result of a failure on the part of researchers to agree on common or standardized POE tools to measure occupant ratings of the built environment [47, 48]. Therefore the empirical analysis in the present paper is based on an "industry standard" post-occupancy evaluation (POE) database from CBE (Center for the Built Environment) at the University of California, Berkeley. CBE's occupant survey questionnaire is one of the most widely used POE tool to date. For example, it is recommended by ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) as a basic evaluation process of building performance measurement [49], and is also prescribed within the IEQ section of green building rating systems such as LEED [50] and Australia's NABERS [51].

Table 2. List of questionnaire items used for the analysis (from CBE occupant survey database)

IEQ Dimensions	Questionnaire items	Survey questions
Thermal comfort	Temperature	How satisfied are you with the temperature in your workspace?
Air quality	Air quality	How satisfied are you with the air quality in your workspace (i.e. stuffy/stale air, cleanliness, odours)?
Lighting	Amount of light	How satisfied are you with the amount of light in your workspace?
	Visual comfort	How satisfied are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?
Acoustic quality	Noise level	How satisfied are you with the noise level in your workspace?
	Sound privacy	How satisfied are you with the sound privacy in your workspace (ability to have conversations without your neighbours overhearing and vice versa)?
Office layout	Amount of space	How satisfied are you with the amount of space available for individual work and storage?
	Visual privacy	How satisfied are you with the level of visual privacy?
	Ease of interaction	How satisfied are you with ease of interaction with co-workers?
Office furnishings	Comfort of furnishing	How satisfied are you with the comfort of your office furnishings (chair, desk, computer, equipment, etc.)?
	Adjustability of furniture	How satisfied are you with your ability to adjust your furniture to meet your needs?
	Colours & textures	How satisfied are you with the colours and textures of flooring, furniture and surface finishes?
Cleanliness & maintenance	Building cleanliness	How satisfied are you with general cleanliness of the overall building?
	Workspace cleanliness	How satisfied are you with cleaning service provided for your workspace?
	Building maintenance	How satisfied are you with general maintenance of the building?
Overall satisfaction	Satisfaction with workspace	All things considered, how satisfied are you with your personal workspace?

CBE has conducted the occupant survey since 2000 and accumulated data from more than 600 buildings with various occupancy types as of June 2010 [52]. It was developed as a web-based survey tool assessing the building occupants' satisfaction ratings across seven core IEQ dimensions including thermal comfort, air quality, lighting, acoustics, office layout, office furnishings, cleanliness and

maintenance. At the end of the questionnaire respondents are invited to rate their overall satisfaction with, and productivity impacts of all aspects of indoor environment considered in the questionnaire [53, 54]. The survey respondents express their satisfaction level with each questionnaire item on the seven-point bipolar scale ranging from '*very dissatisfied*'(coded as -3) through '*neutral*' (coded as 0) to '*very satisfied*' (coded as +3). The core IEQ satisfaction questions included in the analysis are summarised in Table 2; 15 items focused on satisfaction with individual IEQ factors and one item for estimating overall satisfaction with workspace. CBE's database contains POE responses from various types of buildings including offices, hospitals, schools, commercial, residential, industrial, etc., but our analysis is focused exclusively on the office building subset (52,980 responses collected in 351 office buildings). The sample buildings are broadly described as offices, but include educational, public administration and research organisations. The samples were collected in various climate zones in different countries, including Australia (8.5%), Canada (2.4%), and Finland (7.1%), but the majority of surveyed buildings were located in the USA (82%).

Table 3. Cross-tabulation of subject samples by age, type of work and gender

		Female		Male	
		N	%	N	%
		21,452	56.1	16,805	43.9
Age	30 or under	1,614	20.5	1,121	16.1
	31-50	4,135	52.6	3,562	51.3
	Over 50	2,117	26.9	2,265	32.6
	Total	7,866	100	6,948	100
Type of work	Administrative support	1,390	35.3	529	14.2
	Technical	503	12.8	952	25.6
	Professional	1,549	39.3	1,505	40.4
	Managerial/Supervisory	495	12.6	740	19.9
	Total	3,937	100	3,726	100

Filtering out the survey samples with a missing response on gender and any of 16 questionnaire items described in Table 2 reduced the sample to 38,257 complete questionnaires for the current analyses. Brief demographic information of the survey respondents are presented in Table 3. Subjects' gender was cross-tabulated with age and work category. Please note that only 14,814 and 7,663 samples out of 38,257 contained valid values in age and work variables respectively. The study population was broadly categorised by age (30 or under, 31-50, and over 50) and type of work (administrative support, technical, professional, and managerial/supervisory). The distribution across three age groups and four work categories differed between the sexes. The size of youngest age bracket (30 or under) was higher in females (20.5%) compared to males (16.1%), while male occupants had a higher percentage in oldest age bracket (32.6%) compared to females (26.9%). In terms of the subjects' type of work, males reported much higher percentages of technical (25.6%) and managerial/supervisory

classifications (19.9%) than females (12.8% and 12.6% respectively). The percentage of subjects describing their work as "administrative support" was more than two times higher within female group (35.3%) than male group (14.2%). There were significant differences between these two categorical variables (Chi-Square test significance level = 0.000 for both age/type of work and gender), confirming the general picture of the CBE female sample in this analysis as being younger and in lower job classifications than the males.

3.2 Data analysis

Based on the CBE database, the female and male occupants' satisfaction levels (mean scores) with individual IEQ factors (Table 2) were estimated. Differences in mean values were investigated by *t*-test. Also, the percentage of occupants who expressed clear dissatisfaction was estimated for each of the 15 IEQ factors. Percentage of dissatisfied is widely regarded as a meaningful and practical metric in thermal comfort research and facilities management because it can be readily interpreted as an expression of the number of potential complaints [55]. Combined with mean satisfaction score, the dissatisfaction rate quantifies the extent to which female and male occupants respond differently to the various IEQ aspects. Percentage dissatisfied was derived as the cumulative total of votes "*very dissatisfied*" and "*dissatisfied*" (bottom two points on the 7-point satisfaction scale). This classification is directly comparable to that used by Fanger [55] in his mapping from a 7-point scale of thermal sensation (*-3 cold, -2 cool, -1 slightly cool, 0 neutral, +1 slightly warm, +2 warm, +3 hot*) onto a thermal satisfaction/dissatisfaction bifurcation which forms the basis of the very widely used PPD (Predicted Percentage Dissatisfied) index. Fanger defined dissatisfied (the "D" in PPD) as those who vote -2 or -3, +2 or +3, based on the evidence from Gagge et al. [56] indicating that *"... real discomfort is first expressed by those voting higher than +2 or lower than -2*".

In order to investigate the association between gender and IEQ dissatisfaction, a set of logistic regression analyses were performed with gender as the independent variable, and the occurrence of dissatisfaction on each of the 15 IEQ factors as dependent variables. The results of the regression model are reported as odds ratios (OR). The OR represents the ratio of the odds of a particular outcome occurring in one group over the odds of it occurring in another group. An OR greater than 1 indicates that the event in question is more likely to occur in the experimental group compared to the reference group, while an OR less than unity represents a decreased likelihood of occurrence in the experimental group compared to the control. In the current analysis, the values of odds ratios from logistic regression analyses represent the likelihood of being dissatisfied with individual IEQ factors resulting from gender difference. Also, multivariate logistic regression analyses were conducted by including occupant age and work classification among the independent variables.

4. Results

4.1 Mean satisfaction level

Fig. 1 illustrates the mean satisfaction ratings for overall workspace and the 15 IEQ factors by gender. Thirteen of the 15 IEQ factors received positive mean satisfaction scores but 'temperature' received negative mean votes by the female group and 'sound privacy' received negative mean votes by both males and females. In general, thermal/air ('temperature' and 'air quality') and acoustical condition ('noise' and 'sound privacy') were evaluated poorly compared to the rest of IEQ factors. Female occupants' satisfaction ratings were consistently lower than that of males across all fifteen IEQ factors.

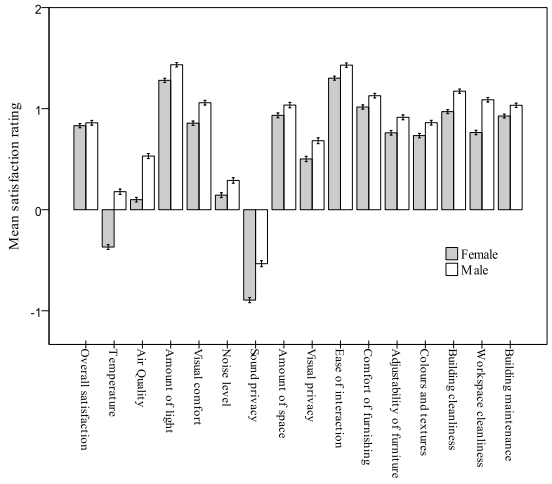

Fig. 1. Mean satisfaction rating (-3 = '*very dissatisfied*', through 0 = '*neutral*' to 3 = '*very satisfied*') for overall workspace satisfaction and various IEQ factors by gender (Error bars represent 95% confidence intervals; N=38,257)

Table 4. *t*-test for the difference of mean satisfaction score between female and male occupant groups

	Mean satisfaction score		*t*-test		
	Female	Male	Mean difference	*t*	Sig.
Overall satisfaction	0.83	0.86	-0.03	-1.77	N.S.
Temperature	-0.37	0.18	-0.55	-29.98	$p<0.001$
Air quality	0.10	0.53	-0.43	-24.70	$p<0.001$
Amount of light	1.28	1.43	-0.15	-9.82	$p<0.001$
Visual comfort	0.86	1.06	-0.20	-12.23	$p<0.001$
Noise level	0.14	0.29	-0.15	-7.79	$p<0.001$
Sound privacy	-0.89	-0.53	-0.36	-18.08	$p<0.001$
Amount of space	0.93	1.04	-0.10	-5.48	$p<0.001$
Visual privacy	0.50	0.68	-0.18	-8.92	$p<0.001$
Ease of interaction	1.30	1.43	-0.13	-8.48	$p<0.001$
Comfort of furnishing	1.02	1.13	-0.11	-6.86	$p<0.001$
Adjustability of furniture	0.76	0.91	-0.15	-8.77	$p<0.001$
Colours & textures	0.73	0.86	-0.13	-7.59	$p<0.001$
Building cleanliness	0.97	1.17	-0.20	-13.34	$p<0.001$
Workspace cleanliness	0.76	1.09	-0.32	-19.43	$p<0.001$
Building maintenance	0.93	1.03	-0.11	-6.95	$p<0.001$

Table 4 indicates that females had lower satisfaction ratings than males on all 15 IEQ factors. Student *t*-tests for these gender differences were statistically significant at $p<0.001$ level for all 15 IEQ factors. The biggest mean difference was observed for 'temperature' (-0.55), followed by 'air quality' (-0.43), 'sound privacy' (-0.36), then 'workspace cleanliness' (-0.32). Although the female group's ratings were lower for all 15 IEQ factors, the evaluation on the overall workspace wasn't significantly different between both sexes ($p = 0.08$).

4.2 Percentage dissatisfied with the IEQ factors

The percentages of female and male occupants expressing clear dissatisfaction ("*very dissatisfied*" or "*dissatisfied*") is graphed for each of the 15 IEQ factors in Fig. 2. The highest dissatisfaction rate was reported for 'sound privacy' (female: 47.0%, male: 39.5%), followed by 'temperature' (female: 30.5%, male: 21.1%). Relatively lower dissatisfaction rates were observed for office furnishing, lighting, and building maintenance issues. The rank order for the IEQ factor dissatisfaction rate was almost the same for both sexes but females consistently registered higher percentages of dissatisfaction. In particular, noticeable gaps between females and males were registered on 'temperature' (9.4%), 'sound privacy' (7.5%) and 'air quality' (6.8%).

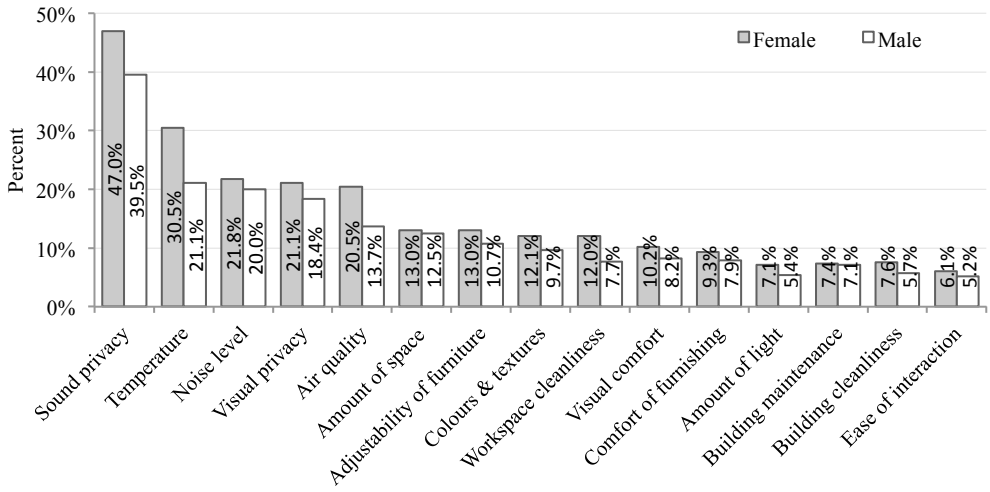

Fig. 2. The percentage of dissatisfied female/male occupants (subjects who rated their satisfaction level with the lowest 2 levels on the 7-point scale) for each IEQ factor

4.3 Association between gender and IEQ dissatisfaction

The relationship between gender and dissatisfaction with IEQ factors was investigated by logistic regression analysis and Table 5 presents the odds ratios (OR). Crude ORs were calculated for the entire occupant samples (N=38,257) while ORs adjusted for age and work category were based on the subset of the dataset (N=7,295) containing valid entries for age and type of work variables. Male gender was set as the reference (OR=1) in the analyses. Therefore, ORs reported in Table 5 indicate

the probability that female occupants express dissatisfaction with IEQ factors relative to their counterparts. For example, OR = 1.65 for temperature can be interpreted as females being 1.65 times more likely to be dissatisfied with temperature of their workspace than males.

Table 5. Crude and adjusted odds ratios (OR) and 95% Confidence Intervals (CI) for IEQ dissatisfaction with respect to female gender (OR=1 for males as the reference)

Dissatisfaction with IEQ factor	Female gender	
	Crude OR (N=38,257)	Adjusted OR (N=7,295)
Temperature	1.65*** [1.57; 1.73]	1.84*** [1.65; 2.05]
Air quality	1.62*** [1.54; 1.72]	1.70*** [1.48; 1.96]
Amount of light	1.35*** [1.24; 1.47]	1.56*** [1.28; 1.90]
Visual comfort	1.28*** [1.12; 1.37]	1.28** [1.09; 1.51]
Noise level	1.12*** [1.06; 1.17]	NS
Sound privacy	1.36*** [1.31; 1.42]	1.35*** [1.23; 1.49]
Amount of space	NS	NS
Visual privacy	1.20*** [1.13;1.25]	NS
Ease of interaction	1.19*** [1.09; 1.30]	1.35** [1.10; 1.66]
Comfort of furnishing	1.20*** [1.11; 1.29]	1.37** [1.12; 1.67]
Adjustability of furniture	1.25*** [1.17; 1.33]	1.53*** [1.29; 1.82]
Colours & textures	1.28*** [1.20; 1.37]	1.48*** [1.25; 1.73]
Building cleanliness	1.37*** [1.26; 1.49]	1.79*** [1.51; 2.11]
Workspace cleanliness	1.62*** [1.51; 1.74]	2.14*** [1.82; 2.51]
Building maintenance	NS	1.30** [1.10; 1.52]

***p<0.001, **p<0.01, NS=Not Significant (p>0.05); Lower and upper bound of 95% CIs are in brackets; Adjusted for age and work category.

Table 5 shows that female gender is significantly associated with higher levels of dissatisfaction than males on most of the IEQ factors. The top three IEQ factors showing the strongest relationship with female gender were identified as ‘temperature’, ‘air quality’, and ‘workspace cleanliness’. When the potential confounding factors of age and type of work were taken into account, the multiple logistic regression analyses produced a broadly similar pattern as the univariate regression analyses, but adjusted ORs increased for most IEQ factors. However, the exception was the association of gender with ‘noise level’ and ‘visual privacy,’ both becoming insignificant after adjustment. Relatively higher adjusted ORs were reported for dissatisfaction with ‘temperature’, ‘air quality’, ‘building cleanliness’, and ‘workspace cleanliness’ in the multivariate analyses. There was no significant association between gender and ‘amount of space’ in either crude or adjusted analyses. Overall, logistic regression analyses identified significant relationships between gender and IEQ dissatisfaction, suggesting that female occupants are more likely to express dissatisfaction with most of the IEQ factors in CBE’s questionnaire, but particularly with thermal environmental conditions, IAQ, and workplace cleanliness.

4.4 Age group

Kim J, de Dear R, Cândido C, Zhang H, Arens E. 2013. Gender differences in office occupant perception of indoor environmental quality (IEQ). Building and Environment. doi:http://dx.doi.org/10.1016/j.buildenv.2013.08.022

In order to more thoroughly analyse the impact of female gender on IEQ dissatisfaction within different age groups, logistic regression analysis was conducted separately on the occupant samples of each age category. Table 6 shows ORs for dissatisfaction with individual IEQ factors resulting from female gender, across the three broad age classifications used in the CBE database. Consistently significant associations between gender and dissatisfaction were observed for thermal, air, sound privacy, interior fit-outs (colours & textures), and cleanliness issues, regardless of occupant age. The largest discrepancies in ORs between the three age groups were observed for 'temperature'. The <=30 year age group females had the highest probability, relative to the males, of expressing thermal dissatisfaction (OR=2.12 for the youngest group, 1.63 for the middle group, and 1.22 for the oldest group). 'Amount of space' showed a significant gender effect only within the oldest group, becoming the only item on which females registered less dissatisfaction than males (i.e. OR < 1).

Table 6. Age stratified odds ratios (OR) and 95% Confidence Intervals (CI) for IEQ dissatisfaction with respect to female gender (OR=1 for male as the reference)

Dissatisfaction with IEQ factor	Female gender		
	30 or under (N=2,735)	31-50 (N=7,697)	Over 50 (N=4,382)
Temperature	2.12*** [1.76; 2.56]	1.63*** [1.47; 1.81]	1.22** [1.06; 1.42]
Air quality	1.42** [1.11; 1.83]	1.69*** [1.48; 1.94]	1.52*** [1.28; 1.82]
Amount of light	NS	1.34** [1.10; 1.63]	1.36* [1.05; 1.75]
Visual comfort	NS	1.29** [1.09; 1.52]	NS
Noise level	NS	NS	NS
Sound privacy	1.26** [1.08; 1.47]	1.34*** [1.23; 1.47]	1.32*** [1.17; 1.50]
Amount of space	NS	NS	0.79* [0.65; 0.96]
Visual privacy	NS	1.22*** [1.09; 1.37]	NS
Ease of interaction	NS	1.49*** [1.20; 1.84]	1.42** [1.09; 1.85]
Comfort of furnishing	NS	NS	NS
Adjustability of furniture	NS	1.30** [1.11; 1.54]	NS
Colours & textures	1.36* [1.03; 1.79]	1.28** [1.09; 1.49]	1.36** [1.09; 1.71]
Building cleanliness	1.59* [1.12; 2.28]	1.56*** [1.33; 1.84]	1.51*** [1.23; 1.84]
Workspace cleanliness	1.76*** [1.30; 2.37]	1.86*** [1.61; 2.16]	1.87*** [1.55; 2.27]
Building maintenance	NS	NS	NS

***p<0.001, **p<0.01, *p<0.05, NS=Not Significant (p>0.05); Lower and upper bound of 95% CIs are in brackets

4.5 Type of work group

Table 7 presents the results of logistic regression analyses conducted on the occupant samples of the four work categories within the CBE database; administrative support, technical, professional, and managerial/supervisory. Within each work category, female gender had a consistently increased likelihood of IEQ dissatisfaction relative to male. In general, temperature, IAQ and cleanliness registered high values of ORs across all four work categories. Female gender had a greater impact on dissatisfaction with 'air quality', 'amount of light' and 'adjustability of furniture' in technical and managerial groups, compared to the other work categories. Administrative work group registered higher ORs for the matters such as interaction with co-workers, cleanliness and building maintenance

issues, while managerial group reported higher ORs for furniture related issues (comfort and adjustability).

Table 7. Work category stratified odds ratios (OR) and 95% Confidence Intervals (CI) for IEQ dissatisfaction with respect to female gender (OR=1 for male as the reference)

Dissatisfaction with IEQ factor	Female gender			
	Administrative support (N=1,919)	Technical (N=1,455)	Professional (N=3,054)	Managerial/ Supervisory (N=1,235)
Temperature	1.96***[1.53; 2.51]	2.07***[1.65; 2.61]	2.07***[1.76; 2.44]	1.75***[1.36; 2.26]
Air quality	1.58** [1.14; 2.18]	1.95***[1.47; 2.59]	1.68***[1.37; 2.06]	1.98***[1.44; 2.73]
Amount of light	NS	2.00** [1.34; 2.97]	1.44** [1.09; 1.90]	2.27***[1.40; 3.70]
Visual comfort	NS	1.43* [1.02; 2.02]	NS	1.53***[1.03; 2.26]
Noise level	NS	NS	NS	1.40* [1.04; 1.88]
Sound privacy	1.26* [1.02; 1.55]	1.55***[1.24; 1.92]	1.46***[1.27; 1.69]	1.53***[1.21; 1.94]
Amount of space	NS	NS	NS	NS
Visual privacy	NS	NS	1.32** [1.10; 1.57]	NS
Ease of interaction	1.66* [1.01; 2.73]	NS	1.35* [1.02; 1.79]	NS
Comfort of furnishing	NS	1.57* [1.09; 2.26]	1.50** [1.14; 1.98]	1.89* [1.12; 3.18]
Adjustability of furniture	NS	1.82***[1.31; 2.53]	1.43** [1.13; 1.82]	2.75***[1.79; 4.22]
Colours & textures	1.61* [1.12; 2.32]	2.06***[1.48; 2.87]	1.42** [1.13; 1.77]	1.62* [1.12; 2.36]
Building cleanliness	2.09***[1.40; 3.11]	1.89***[1.34; 2.67]	1.87***[1.46; 2.40]	NS
Workspace cleanliness	2.34***[1.63; 3.35]	1.96***[1.37; 2.81]	2.11***[1.65; 2.71]	1.58* [1.11; 2.24]
Building maintenance	1.57* [1.05; 2.36]	NS	1.37* [1.08; 1.73]	NS

***p<0.001, **p<0.01, *p<0.05, NS=Not Significant (p>0.05); Lower and upper bound of 95% CIs are in brackets

5. Discussion

The analyses conducted on CBE's POE database demonstrated that satisfaction with various IEQ factors differed between the sexes. Significant gender differences were observed for mean satisfaction level with all IEQ factors (Table 4), with females being consistently less satisfied. This study also focused on the occupants' expressions of clear dissatisfaction, as an indicative measure of potential IEQ complaints. Again the percentage of dissatisfaction was consistently higher in the female group (Fig.2). From the perspective of facilities managers whose job it is to manage complaints from office building occupants, the percentage of people dissatisfied with indoor environmental aspects can be practical because the criticism from the occupants is already embedded in that index. In this regard, Fig. 2 implies that female occupants can be more critical about the quality of their workspace environment than their male counterparts.

Interestingly, although females expressed lower satisfaction levels across the 15 IEQ factors in question, the overall rating on their workspace environment didn't differ between the sexes (Table 4). In other words, females and males showed little difference in their overall satisfaction with workspace, despite females being consistently less satisfied with each of the specific IEQ issues, especially with thermal environmental conditions and indoor air quality. Previous research has shown

that the prevalence of health symptoms and IEQ complaints was higher in air-conditioned buildings than in naturally ventilated buildings [14]. Considering the fact that a majority of survey responses used in our analyses were drawn from air-conditioned office buildings (73.5% of total survey samples, 97.5% if include mixed-mode buildings), significantly lower satisfaction with thermal and air quality suggests that females are more sensitive than males to indoor environmental conditions delivered by HVAC systems.

Logistic regression analyses conducted on the entire occupant sample showed that being female was significantly associated with IEQ dissatisfaction, particularly with indoor thermal, air quality and workspace cleanliness issues, which corroborates the findings of previously published field research; women have previously been reported as being less satisfied with indoor thermal environment [11, 12, 23, 24, 29], more sensitive to indoor air problems such as stuffy air, draught, and dust [45], and report higher prevalence of indoor-air-related symptoms [e.g. 21,22].

Differences between the thermal comfort responses of females and males in field studies have sometimes been attributed to clothing differences between the sexes [11, 12]. In those large office building studies females were observed to have greater variability in whole ensemble clothing insulation (clo), and clothing insulation is often distributed across the body surface differently for female office workers compared to males. These observations have been used to explain the heightened thermal sensitivity of female office workers. Detailed clothing garment checklists in office buildings in diverse climate zones reported that females' average clo-values were about 0.1 unit lower than males [11, 12], which equates to almost a full degree (K) of operative temperature according to the industry-standard PMV index [55]. Furthermore, local discomfort resulting from greater clothing insulation variability among female office workers might have contributed to the higher levels of thermal unacceptability for females in the current study. A recent laboratory experiment that found a high correlation between the whole-body thermal sensation and local thermal sensation among females tends to support this argument [39].

Others [20] attribute the gender effect on thermal comfort to the differences in metabolic rate between two sexes – based on the finding by McNall et al. [57] that females have a lower metabolic rate per unit surface area under sedentary activity than males. Physiological differences between the two sexes may have an influence on their thermal responses. In their review article Stocks et al. [58] concluded that the menstrual and other regulatory hormones affected thermal comfort responses, thermoregulation and thermogenic thresholds of females. Havenith and Middendorps' [59] laboratory study suggested that gender differences in physiological responses to heat stress in warm-humid and hot-dry exposures can be attributed to factors such as percentage of body fat and the surface-to-mass ratio. In relation to females' sensitivity to indoor air quality problems or health symptoms, some researchers infer that the reason may be due to differences in hormonal levels giving different

psychosocial thresholds for the stimuli [17]. Others related use of eye make-up to increased prevalence of the SBS symptom of eye irritation among females [42, 60].

The marked differences in the responses to various aspects of indoor environment, as reported in this paper, suggest there is a discrepancy between females and males. However, before generalising it is prudent to examine potentially confounding factors. Many contributors to the SBS research literature have emphasised the inclusion of psycho-social or work-related factors when investigating sex differences [30, 37, 46, 61]. That is, the frequently reported female occupants' health symptoms or complaints could be influenced by personal or occupational characteristics unrelated to indoor environment such as job-related stress, lack of control of work, low job pride resulting from low position within the organisational hierarchy. For example, it has reported that work-related symptoms were the highest in clerical or secretarial workers, followed by technical or professional workers, and lowest among managers [22]. Therefore, in this paper, multiple logistic regression analysis was performed to take into account the effects of seniority and work characteristics on the outcome variable. Adjusted ORs in Table 5 showed a significant association of female gender with dissatisfaction with various IEQ factors. Moreover, ORs tended to *increase* after controlling for age and work characteristics, refuting the hypothesis that psychosocial factors rather than gender accounted for the differences observed between the sexes in office building studies [13, 21, 40].

Messing and Stellman [62] were highly sceptical about the gender differences reported in the previous researches. They pointed out the risk of overemphasising the differences without considering all relevant individual characteristics such as fitness, nutritional differences, ethnicity, culture, and social class. To be sure, such contextual and personal factors are important to the responses of individuals, but we believe that variability in these factors has been largely normalised in such a large occupant sample collected from such a diverse building stock drawn from such a variety of geographic and climatic regions within CBE's database.

6. Conclusion

The comprehensive literature survey in Table 1 highlighted general consensus that gender differences exist, particularly in SBS symptomology and thermal discomfort. Our analyses based on 38,257 office occupant samples further reinforce these earlier findings. However, the present study generalises the gender effect beyond indoor air quality and thermal conditions, to the remaining IEQ factors. The present analysis predicts that female office workers are significantly more likely to complain about the IEQ factors than their male counterparts. And yet, despite females' higher level of dissatisfaction with *specific* IEQ factors, *general or overall* workspace satisfaction ratings showed no difference between male and female samples.

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