Effect of Indoor Environmental Quality (IEQ) to the Human Occupation Health and Performance in Buildings

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Abstract

This paper focuses on the importance and occupant satisfaction with IEQ in building as well as the effect of IEQ towards occupants' satisfaction. IEQ is an important quality aspect of buildings as it affects the health of the occupants. The building's occupants are the most reliable source of information as regards their needs and comfort requirements for IEQ. This research applied Post-Occupancy Evaluation (POE) as a method to indicate the needs of the building's occupants, their satisfaction and comfort level. The research is based on a case studies approach whereby a questionnaire survey was conducted among twenty five (25) organizations involved in managing office buildings with 115 questionnaires returned to examine overall occupant satisfaction from aspects of IEQ in buildings and to determine the occupants' satisfaction level with the building. The analysis is based on survey responses collected from the occupants of the buildings. The findings revealed that indoor environment consists of lighting, air quality and aesthetic environment. These classifications were made based on the factor analysis done with 22 attributes of the indoor environment. Majority of the occupants are satisfied with their health conditions and do not face any serious health problem. However, the occupants highlighted that the environment condition, health conditions, air movement, ventilation and freshness are important criteria to ensure their satisfaction and comfort. This study provides insights into how occupants perceive the indoor environment, comfort and occupant satisfaction and the set of problems appearing in the buildings.

Keywords: Indoor environment quality; occupants; satisfaction; building; comfort; Malaysia

1. Introduction

Building is a fundamental component which provides shelter and facilities for individuals to perform daily task. The quality of indoor air is very important for human health and well-being because most people spend their time indoors; in offices, schools and homes (Di Giulio et al., 2010). The health risks of exposure to indoor air pollution are greater than those caused

by outdoor air pollution. Various aspects of the indoor environment affect human well-being and performance. The air and environment can be affected by chemical, biological and physical agents resulting from the occupants' activities and the presence of volatile organic compounds (VOCs), from other contaminants and pollutants released by certain building materials or from the ambient environment (Shuang, 2011). Other factors affecting the indoor environment quality (IEQ) are lighting, natural ventilation, thermal quality and indoor air quality (IAQ). However, high-performance design and green buildings can provide a better and healthier environment for the occupants (Kamaruzzaman et al., 2011).

With rising awareness of the role of the indoor environment on occupants' productivity and efficiency, there are a few research obtained feedback from occupants (Huang et al., 2012; Kamaruzzaman et al., 2011; Kim et al., 2013; Ncube and Riffat, 2012). Occupants' opinion towards building indoor environment can be obtained through questionnaire survey. Kamaruzzaman et al. (2011) stressed that the findings from the questionnaire survey should be able to assist in identifying particular aspects of the environment that require adjustment and improvement and aim to provide a better internal environment for the occupants.

The most prevalent and established data collection method across diverse disciplines including psychology, social, health and building sciences, is an occupant survey which results in post-occupancy evaluation (POE). Previous researches that adopted this method are Kamaruzzaman et al., 2011 and Huang et al., 2012. Kim et al. (2013) carried out a research to study the relationships between the indoor environment and the behaviour, perception and comfort of the building's occupants. It is found that female respondents are less satisfied with all IEQ factors, with the lowest satisfaction scores for IEQ factors given to temperature, followed by air quality and acoustical conditions (noise and sound privacy).

Occupant satisfaction can be defined from various perspectives, depending on the scope of the study. Frontczak et al. (2012) stated that occupant satisfaction is associated with IEQ (thermal, visual, acoustic and air quality) and workspace as well as building features (including size, aesthetic appearance, furniture and cleanliness). The authors highlighted that the degree of importance of the indoor environmental parameters varies between studies, but thermal environment is generally ranked slightly higher compared to air quality, acoustic environment and visual environment. Sound privacy and IEQ (temperature, noise and air ranked highest level of dissatisfaction. The most important factors for workspace satisfaction among the occupants are the amount of space, noise level, and visual privacy.

IEQ is an important quality aspect for office buildings. From the occupants' perspective, the ideal situation is an indoor environment that satisfies everyone. Bluyssen and Cox (2002) mentioned that unhealthy indoor environment can affect building occupants' health. Several factors can contribute to a healthier indoor environment including:

i. Source control: reducing the emissions from sources of indoor pollution

ii. Ventilation: reducing the exposure to pollution sources

iii. Maintaining comfortable physical conditions: temperature, humidity, and lighting

The negative effects of poor IEQ are physical discomfort, such as fatigue and sick building syndrome. The poor quality of facilities and building design is associated with the occupants' performance and achievement. The building's interior and characteristics are a major influence on exposure to indoor pollutants and other indoor physical parameters. Studies done by Kamaruzzaman et al. (2011) and Wolkoff (2013) have identified several criteria that affect the occupants' health and work performance, but there is still a gap in the information about occupants' assessments of IEQ. Thus, this provides an impetus to this particular study area. This paper applies Post-Occupancy Evaluation (POE) as a method to indicate the needs of the building's occupants, their satisfaction and comfort level. Thus, it involves the systematic application of POE and occupants' perceptions about the building or workspace.

The broad aim of this paper is to contribute to the discussion of the impact of overall occupant satisfaction from aspects of IEQ in buildings and to determine the occupants' satisfaction level with the building with particular reference to buildings in Kuala Lumpur, Malaysia. The analysis is based on survey responses collected from the occupants of the buildings. The findings of this study provide insights into how occupants perceive the indoor environment and the set of problems appearing in the buildings. The findings contribute to the existing knowledge about perceived comfort and occupant satisfaction.

2. Research design and methodology

A questionnaire survey was developed on the basis of extensive literature reviews. The primary aim of the questionnaire survey is to examine overall occupant satisfaction from aspects of IEQ in buildings and to determine the occupants' satisfaction level with the building. Bluyssen and Cox (2002) considered that IEQ is treated as part of TOBUS, namely thermal comfort, indoor air quality (humidity, pollutants and ventilation), lighting and noise; they incorporated work-related factors, personal characteristics and ergonomics in their study. Wolfinbarger and Gilly (2003) explained that the types of questionnaire may consist of multiple-choice questions, close-ended questions and Likert-type questions. The questionnaire for this study is adapted from Levermore et al. (1999),who developed in United Kingdom and which is used by a number of organizations including consultancies in London.

Likert style questions were employed to rate 22 factors relating to satisfaction with the office and building. The questionnaire comprises important factors in design of the ideal office and the comfort of the occupants of the building. The research is based on a case studies approach whereby a focus on twenty five (25) organizations involved in managing office buildings is conducted. The office buildings selected consist of low, medium and high rise which represent the typical layout settings located in Kuala Lumpur, the capital of Malaysia.

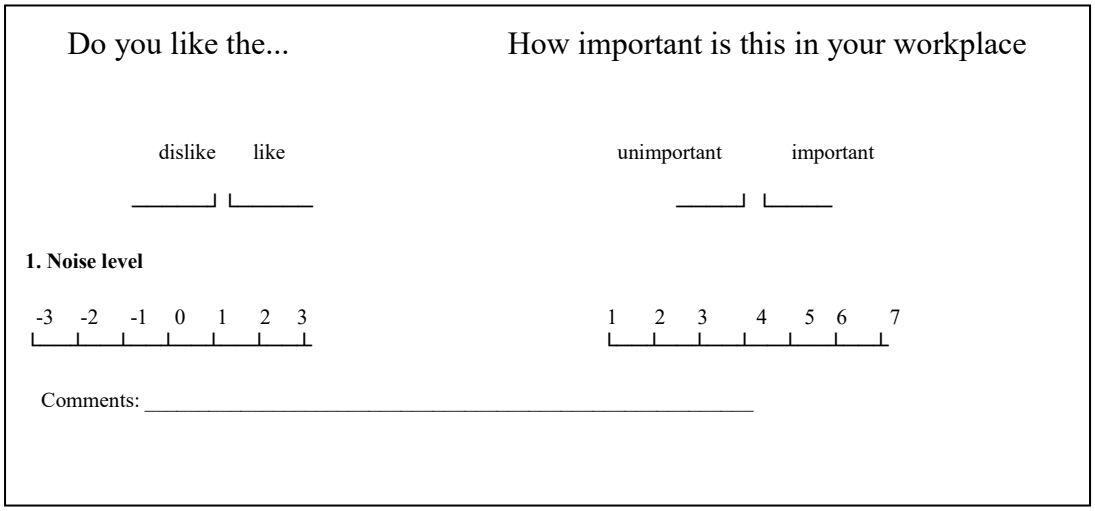
Through the support of the management, building occupants were gathered and a short explanation about the survey was presented. All respondents were allowed to complete the questionnaires for approximately one hour before collecting back the questionnaires.
The questionnaire is divided into three main sections. Section A deals with the demographic profile of the occupants; section B deals with comfort levels, using semantic differential rating questions; and section C asks about the degree of likeness and importance in their office to determine the occupants' satisfaction with the building. According to Lai and Yik (2007), it is important that the attributes which are indoor environment factors should be understandable by all levels of respondent, not only professionals but also the end users who may have little knowledge of some technical terms. In other words, jargon must be avoided in order to gain responses about IEQ attributes without doubt or confusion. The length of the questionnaire structured in short and straight forward manner so that it does not cause fatigue to the respondents.

2.1. Liking score

Section C, which is the main feature of the questionnaire, explores questions involving noise, lighting, temperature, humidity and ventilation . The control of ventilation, temperature and lighting are important elements of the comfort index in the evaluation of IEQ issues by the building's occupants (Bluyssen and Cox, 2002). Therefore, the occupants were asked to rate in a seven-point Likert scale for "User satisfaction" and "Degree of importance". By combining all 22 factors relating to the internal environment of the building, the questionnaire could be used to elicit an occupant satisfaction score and a benchmark for building satisfaction. The factors include the following:

Q1	-Noise Level	Q12	-Smell in the room
Q2	-Electric lighting	Q13	-Health when in the room
Q3	-Amount of daylight	Q14	-Colours of the room
Q4	-Glare level in the room	Q15	-Attractiveness of the room
Q5	-Glare level around desk	Q16	-Control over local environment
Q6	-Distance to the windows	Q17	-Workspace
Q7	-Office temperature	Q18	-Privacy
Q8	-Ventilation	Q19	-Immediate colleagues
Q9	-Amount of air movement	Q20	-Management
Q10	-Freshness of the room	Q21	-Office, in general
Q11	-Humidity level in the room	Q22	-Outward appearance

Section C used a double Likert scale for liking and importance of a number of factors relating to the indoor environment and the organisation. The seven-point scale for like and dislike used in the questionnaire is shown below:



These types of scale are used to increase the ease of understanding, which is important for a self-administered questionnaire. The seven-point like or dislike scale is another option for the respondents to designate the importance of the factors in designing their ideal office or room. Note that, even though few respondents considered that any of the stated factors were unimportant and thus of negative value, this scale is still used and was not reduced in order to maintain consistency and avoid confusion. The importance rating was defined as follows:

Scale	Definition	Explanation
1	Extremely unimportant	The evidence of least favoring one attribute over another is of the highest possible order of affirmation
2	Unimportant	The attributes are perceived as unimportant
3	Slightly unimportant	Experience and judgment slightly unfavourable
4	Moderately important	Experience and judgment moderately favour one attribute over another
5	Strongly important	Experience and judgment strongly favour one attribute over another
6	Very strongly important	An attribute is strongly favoured and its dominance demonstrated in practice
7	Extremely important	The evidence favouring one attribute over another is of the highest possible order of affirmation

Furthermore, the occupant satisfaction with the building using the 7-point Likert scale ranged from -3 (strongly dislike) to 3 (strongly like) for the indoor environment factors.

Scale	Definition	Explanation
-3	Extremely dislike	The evidence of least favoring one attribute over another is of the highest possible order of affirmation
-2	Dislike	The attributes are perceived as disliked
-1	Slightly dislike	Experience and judgment slightly unfavourable
0	Neither like nor dislike	Experience and judgment moderately favour one attribute over another
1	Strongly like	Experience and judgment strongly favour one attribute over another
2	Very strong like	An attribute is strongly favoured and its dominance demonstrated in practice
3	Extremely like	The evidence favouring one attribute over another is of the highest possible order of affirmation

The questionnaire consists of both the occupants' ratings of their satisfaction with the internal environment and their ratings on how important they find these environmental conditions. The first part of the analysis is to find the satisfaction score. The satisfaction score of a building (an overall rating for a building's indoor environment) can be determined from the following equation (Levermore, 1994;Levermore and Leventis, 1997; Levermore et al., 1999):

$$OLS = \left[\frac{\sum_{k=1}^{n} \sum_{j=1}^{m} i_{j,k} l_{j,k}}{mni_{max} l_{max}} \right] 100 \qquad (1)$$

where
j = questionnaire number
k = question number
i = importance rating $1 < i > 7$
i_{max}= maximum value of i, (7)
l_{max}= maximum liking rating l (+3)
l = liking rating $-3 < l > +3$
m = number of filled in questionnaires
n = number of questions in the score

The second part of the analysis provides a graphical representation of the totals for each answer. This is called a fingerprint and normalizes each question to a score between +100% and -100% (Levermore, 1994; Levermore and Leventis, 1997; Levermore et al., 1999). The equation is as follow:

$$\mathrm{FLS} = 100\left[\frac{\sum_{j=1}^{m} i_{j,k} l_{j,k}}{m i_{\max} l_{\max}}\right] \quad (2)$$

The third part of the analysis is similar to the second. However, by using the equation below, a normalized individual score for each person can be calculated.

$$\mathrm{FLS} = 100\left[\frac{\sum_{k=1}^{n} i_{j,k} l_{j,k}}{n i_{\max} l_{\max}}\right] \quad (3)$$

This score will be between +100% and -100%.

3. Results

(a) Demographic profile of the occupants

Among twenty five (25) organizations involved in managing office buildings, 115 questionnaires returned. Thus, the findings of this research were based on the 115 questionnaires returned by the occupants of the buildings. The descriptive analysis of the general information is illustrated in Table 1, including the gender, profession, age, hours spent using visual display unit (VDU), hour spent at desk and hours spent in building.

Table 1

The findings of the study revealed that majority of the respondents are professional female (57.4%) aged between 21 to 30 years old. Most of the respondents stay in the building for less than 8 hours but spent most of their time using visual display unit (VDU) that is around 4 to 5 hours per day.

(b) Satisfaction levels of the occupant

The audit satisfaction score revealed that majority of the occupants are satisfied with the indoor environment. The occupants are very satisfied with the office environment with a score of +1.27 (highest positive score). In contrast, the occupants argued that they are not satisfied with the distance from the window (least positive score, +0.54), followed by glare level in the room (+0.55) and glare level around desk/VDU (+0.57). It can be seen that the

lowest ranks of all the satisfaction attributes are related to glare. Thus, the glare level is an important consideration in determining building occupants' satisfaction and comfort. Providing an optimum and good environment is essential to increase the productivity of the occupants as majority of the respondents spend almost 8 hours a day in the building.

Figure 1

(c) Importance factors of IEQ

Figure 2 illustrates the ranking of IEQ factors according to the importance. The distance from the window was by far the least important factor, followed by room glare, desk/VDU glare, and daylight. The glare level may result from the lighting and being carefully designed for VDU use. The most important factors are control over the environment, health, air movement, ventilation and freshness. It can be seen that the environment and ventilation system of the indoor environment is very critical in ensuring the comfort of the building occupants.

Figure 2

(d) Comfort level of the occupant

The comfort level of the occupants is measured using a 7-point Likert scale. The elements to be considered in identifying comfort level include aesthetics, relaxing, colour, brightness, glare, draught, heat, noise and dryness. Figure 3 illustrates the comfort levels of male and female respondents, showing that both male and female are in the comfort zone, since the mean values of all elements are above 3.00. The respondents are satisfied and comfortable with all aspects in the current room.

Figure 3

(e) Factor analysis

The variables were adequately defined by this factor solution. Simplicity of structure was assessed by inspection of the factor loading; this revealed some very high correlations and many low correlations between variables and factors. Thus variables were ordered and grouped according to the factor loadings and interpretative labels suggested:
Factor 1 is labelled as Lighting. It is associated with the factors of noise, lighting, daylight, glare level in room, glare level at VDU, distance from window, and temperature.
Factor 2 is labelled as Air Quality. It is associated with the factors of ventilation, air movement, freshness, humidity, smell and health.

Factor 3 is labelled as Aesthetic Environment. It is associated with the factors of colour, attractiveness, control, working space, privacy, colleagues, management, office, and outward appearance of building.

(f) Relation between IEQ and occupant satisfaction

Three factor scores were generated from the occupant responses using the regression method for further analysis.

Assessing the impact of the IEQ on occupant satisfaction

Majority of the variation in occupant satisfaction (58%) was accounted for IEQ (lighting, air quality and aesthetics). The standardized β values also explain the importance of the socio-psychological factors in the model used in this study. It gives a measure of the contribution of each independent variable to the model. The finding shows that aesthetics is the most influential factor for occupant satisfaction ($\beta=0.593$, $t=6.46$, $p<0.05$) while lighting and air quality did not significantly influence satisfaction with the building.

Table 2

Table 3 illustrates the strength of the relationship between IEQ and occupant satisfaction. The significance value for the correlation of this study is $p<0.01$, which is an acceptable significant level of the study at $p<0.1$, $p<0.05$ and $p<0.01$. Therefore, all the IEQ has a positive significant relationship with occupant satisfaction in the building, with lighting ($r=0.351$, $p=0.01$), air quality ($r=0.402$, $p=0.01$) and aesthetics ($r=0.405$, $p=0.01$). Therefore, the findings revealed that the occupants are satisfied with all the criteria of IEQ in the building. Furthermore, this study explained that the stronger the lighting, the higher the occupant satisfaction. In short, occupant satisfaction increases when the occupants are satisfied with the lighting, air quality and aesthetic environment in the building.

Table 3

4. Discussion

The findings of the research revealed that the indoor environment consists of lighting, air quality and aesthetic environment. These classifications were based on the factor analysis done with 22 attributes of the indoor environment. This is in line with the research carried out by Groth (2007), which highlighted that the concept of the indoor environment includes all aspects of the relationship between the occupants and contents of a building as well as their surroundings; it can be considered in terms of climatic and non-climatic aspects.

This study found that the occupants were less satisfied with the distance from the window, glare level in the room and glare level around desk/VDU. Most of the occupants spend almost 8 hours a day in the building, so the glare level is very vital. The dissatisfaction among the occupants was due to the low level of the glare and distance from the window. The occupants

spend a lot of time inside the buildings, where physical conditions influence their wellbeing and indirectly influence their performance and productivity. The respondents ranked control over the environment, health, air movement, ventilation and freshness as important factors of IEQ. These findings support the previous study where important IEQ factors for occupant satisfaction were the amount of space available for individual work, noise level, and visual privacy (Frontczak et al., 2012). In terms of comfort level, the respondents were satisfied with the condition of the current room. In short, the occupants were comfortable with the appearance, serenity, colour, brightness, glare, noise and temperature of the building or their room.

This study found a moderate positive relationship between IEQ attributes and the occupants' satisfaction with the buildings. The extent of the influence and relationship between these attributes can be impacted by gender and type of respondent and by duration of stay in the building (Lai and Yik, 2007; Choi et al., 2010). The duration of stay in the building also influences the relationship between these attributes. The factor of adaptation affects the responses of the study. The level of satisfaction with the IEQ condition among the occupants in the buildings is different according to the duration of their stay. In addition, Agha-Hossein et al. (2013) pointed out that the employees' self-reported productivity, well-being and enjoyment at work increased with a higher level of satisfaction towards work environment. This means that the work environment significantly influences the productivity and performance of the building occupants. Thus, the management should provide a good working environment to ensure the greatest satisfaction level among the occupants of the building. All the IEQ factors should be assessed in order to provide comfort and satisfactory conditions for all the occupants of the buildings. On the other hand, further studies are needed to ensure that occupant satisfaction will be maintained.

5. Conclusion and Policy Implications

The assessment of occupants' satisfaction towards IEQ in buildings is critical because it can affect the occupants' health, comfort, performance and productivity. This study highlighted the needs for an assessment of IEQ satisfaction among occupants. The assessment act as a pioneer in assessing indoor environment problems based on human's view and perception. Indoor environment study is essential in order to satisfy the requests linked to critical functions of occupants because most people spend their time living inside buildings rather than outdoor. The study of IEQ is complex and made up of many factors, which it may be difficult to disentangle.

The paper presents the comparison of results from the questionnaire survey. The satisfaction of occupants is affected by the comfort level of the building environment. This study found that the occupants are less satisfied with daylight, glare level and distance from the window. It is noted that they are dissatisfied with their current workspace. Thus, it is suggested that the

interior designer should focus to maximize workspace satisfaction in the aspect of amount of space and storage, daylight and glare level. Occupants who are satisfied with their workspace will have improved job satisfaction, work performance and productivity. In conclusion, the occupants' satisfaction depends on their satisfaction with the indoor environment elements, but perception can vary depending on individual characteristics.

In addition, IEQ can also contribute to energy saving. Sarbu and Sebarchievici (2013) noted that the energy consumption of buildings depends on the criteria used for the indoor environment (temperature, ventilation and lighting), building design and operation. The design of the rooms can reduce energy consumption and influence the comfort levels.

Practical implication: All the actors, namely designers, engineers, developers and facility managers, should understand the needs of the building's occupants and this is an important issue that needs to be addressed. Indeed, this study was conducted in order to identify the occupants' needs and satisfaction and to address the issues related to their satisfaction. Therefore, all the actors should concentrate on these issues because they are directly involved in the building and operation process, in order to provide the customers with extra value.
This study concludes that occupant satisfaction with IEQ can have a significant impact on creating the changes to improve the building's environment. It provides lessons and feedback for owners and parties involved, directly or indirectly, in environmental improvement works. Thus, it can lead to enhancing the indoor environment by addressing the changing occupants' needs. Secondly, this study could empower end users and provide a benchmark to identify building design and its environmental management to meet the occupants' needs. Finally, it identifies the problems that can lead to the disruption of building performance and deterioration of the building.

Further studies can focus on understanding the differences and association between the factors that impact the occupants' satisfaction that is the differences in gender, type of respondent and duration of stay in the building as affected by the IEQ attributes. Exploring whether a variable is causally linked or different to a particular IEQ attribute can provide a better understanding of the differences between IEQ and occupant satisfaction. Therefore, these findings and knowledge can lead to further improvements in the indoor environment of buildings.

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Table 1: Occupant's Information

Variables	Descriptions	Percent (%)
Sex	**Female**	**57.4**
	Male	42.6
Occupation	**Clerical/Secretarial**	**23.5**
	Professional	31.3
	Managerial	19.1
	Other	26.1
Age	**<20 years**	**4.3**
	21-30	49.6
	31-40	26.1
	41-50	12.2
	51-60	6.1
	>60 years	1.7
Hours spent using visual display unit (VDU)	**0-1h**	**7.8**
	1-2h	4.3
	2-3h	10.4
	3-4h	15.7
	4-5h	34.8
	>5h	27.0
Hour spent at desk	**< 5 hours**	**55.5**
	< 8 hours	37.4
	<10 hours	5.2
	12h	1.7
Hours spent in building	**< 8 hours**	**56.5**
	8 to 12 hours	38.3
	>12 hours	2.6

Table 2: Influence of indoor environment quality towards the occupant's satisfaction

Construct Variables	ERP System Usage		t value	Sig.
	b value	Standardize β		
Lighting	.104	.104	1.43	.16
Air Quality	.132	.143	1.55	.13
Aethestic	.526	.593	6.46	.00
R		.76		
R-squared		.58		
Adjusted R-squared		.57		
F		51.55		
Sig F change		.00		

Table 3: Association of indoor environment quality and occupant's satisfaction

No	Construct Variables	1	2	3	4
1	Satisfaction	1	.351**	.402**	.405**
2	Lighting	.351**	1	.501**	.493**
3	Air Quality	.402**	.501**	1	.729**
4	Aethestic	.405**	.493**	.729**	1

** Correlation is significant at the 0.01 level (2-tailed)

Figure 1

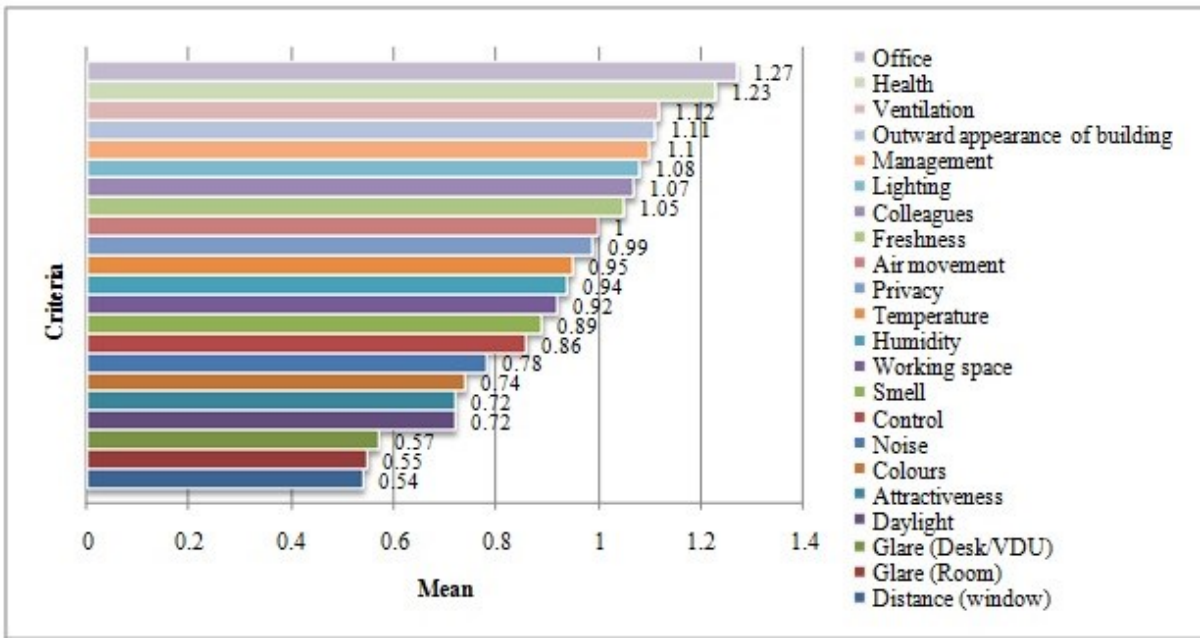


Figure 2

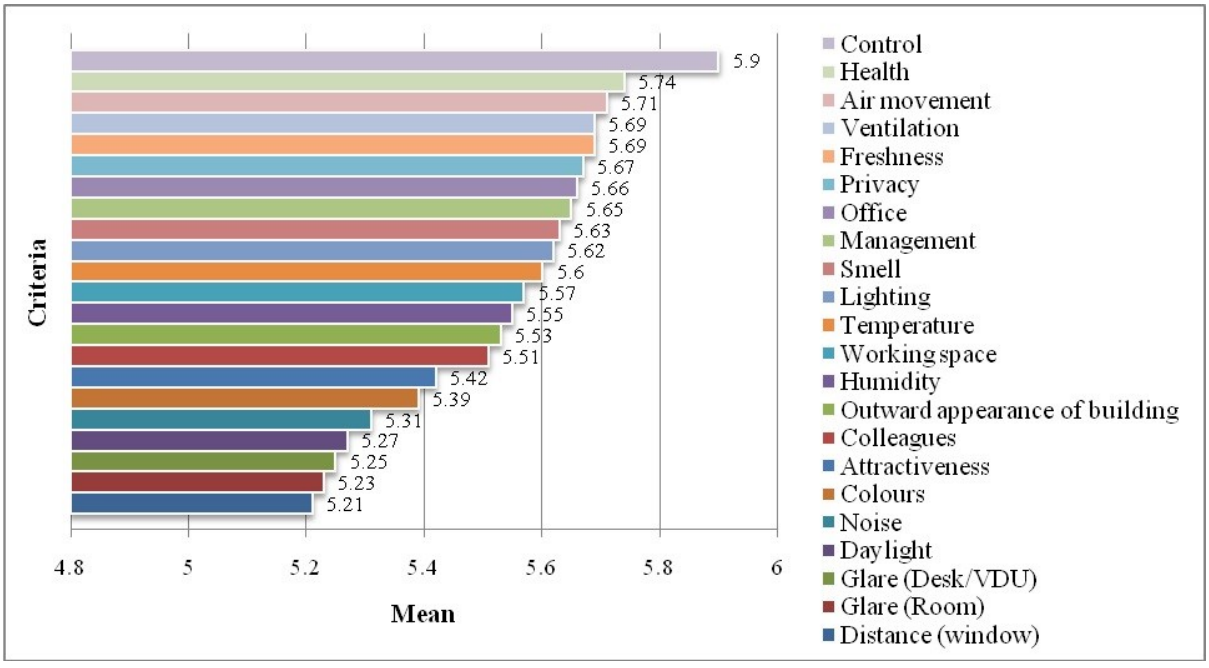
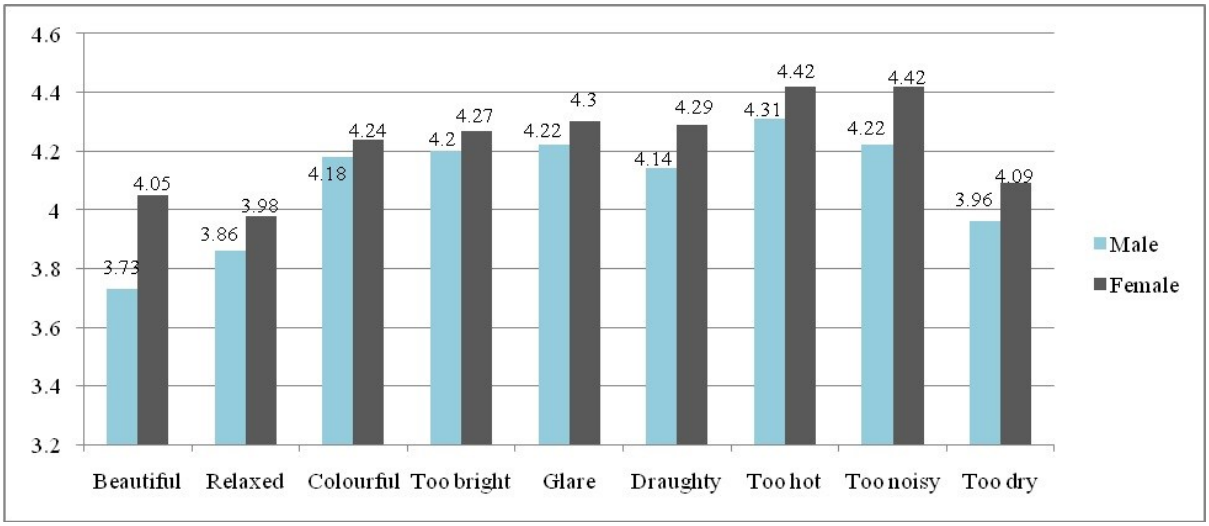


Figure 3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Beautiful
Relaxed
Colourful
Too bright
Glare
Draughty
Too hot
Too noisy
Too dry
Male
Female