

QUESTIONNAIRE SURVEY ON FACTORS INFLUENCING OCCUPANTS' OVERALL SATISFACTION ON DIFFERENT OFFICE LAYOUT IN A MIXED-HUMID CLIMATE

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ABSTRACT: Open-plan offices seem to be more common these days in comparison with enclosed private configurations. This layout is commonly assumed to ease communication, teamwork and interaction between coworkers and increase workspace satisfaction while enabling airflow and passive design strategies. However, there has been little attempt at quantifying pros and cons in terms of occupant satisfaction in open-plan office layouts. The research seeks to identify overall satisfaction/dissatisfaction of occupants in different office layouts, and to determine the differences between occupants' reported office layout and other reported factors. These factors include gender, age, view, working hours, visual comfort, and thermal comfort. The survey study was sent to occupants in office buildings (n=1,026) that are located in mixed-humid climates. The results show that the highest satisfaction ratings were reported by occupants in enclosed offices and open-offices with low partitions. The results also show that the open-office spaces with high partitions had lower satisfaction appraisals in comparison with lower partitions across 7 IEQ factors except 'view'. In addition, between open-plan offices, satisfaction with 'quality of light' and 'thermal condition' slightly increased as the height of partitions decreased. These findings enhance our understanding of occupant satisfaction by indicating that increasing partition height contributes to higher dissatisfaction among office workers.

KEYWORDS: Overall satisfaction, Office layout, Mixed-humid climate, Open-plan office, Survey study

INTRODUCTION

Oldham (Oldham, Cummings, and Zhou 1995) defined the office layout as "how the arrangement and boundaries of workspaces are laid out". In the 1950's, a team from Hamburg, Germany formulated the idea of the open office for the purpose of better communication. In recent years, we have faced a transition in the form of office layouts from cellular or private offices to different types of open-plan offices. In 2011, Matthew Davis (Davis, Leach, and Clegg 2011) reviewed over one-hundred studies about office spaces. He compared open offices with standard offices and concluded that disadvantages (decreased productivity, damaged creative thinking, and declined satisfaction) of open offices undermined the benefits (increased communication between coworkers). Open offices may be better depending on certain ages and specific work types. A considerable amount of literature has grown around the theme of understanding how the physical environment in office buildings affects occupant satisfaction. Previous research has established that the negative impacts of an open-plan office on occupants perception can decrease satisfaction (Brennan, Chugh, and Kline 2002, Sundstrom, Herbert, and Brown 1982) and increased distraction (Kaarlela-Tuomaala et al. 2009). Another study by (Kim and de Dear 2013) compared enclosed private offices and open-plan offices in terms of various IEQ factors. The results showed that enclosed offices had better performance than open-plan offices in most of IEQ factors. A study by (Liang et al. 2014) examined the difference between conventional offices and green offices. He found a significant difference between the mean satisfaction score of green and conventional offices. Another study (Danielsson and Bodin 2008) identified the impact of different office types on worker job satisfaction by considering age, gender, and job rank. The results showed that the workers in shared room offices and cellular offices had the highest job satisfaction. Recently, study by (Choi, Aziz, and Loftness 2010, Schiavon et al. 2016) investigated the impact of occupant gender and age on thermal satisfaction in office layouts and the study revealed that females are more dissatisfied with thermal condition than males. The goal of this study is to assess the parameters that impact the overall satisfaction of different office layouts. First, this paper identifies the overall occupant satisfaction/dissatisfaction of different office layouts. This study also explores the importance of various IEQ factors in relation to the occupants' overall satisfaction. The following research questions are addressed in this paper:

1. Do different office layouts affect an occupant's overall satisfaction in terms of various IEQ factors?
2. Is the importance of various IEQ factors different among occupants in office layouts?

1.0 METHOD

1.1. Occupant survey

The questionnaire used for this study was sent by email to building occupants to assess the occupants' satisfaction ratings for various IEQ aspects. These aspects include thermal comfort, visual comfort, overall workspace satisfaction,

and the office layouts. Occupants in three office buildings completed a set of anonymous questionnaires. To measure the building occupants' satisfaction level five-point scale ranged from very dissatisfied/strongly disagrees (scale 1) to very satisfied/strongly agrees (scale 5) was used. Table 1 summarizes the questionnaire items used in the analysis for this study. The survey typically takes five minutes for a participant to complete. Background information about occupants such as the participants' demographics, the type of work they are engaged in, the time spent at the workspace, the workspace layout, and the type of work they are doing is collected at the beginning of the survey. Depending on the availability, floor plans of the surveyed building were collected in order to better understand the building's spatial characteristics and space allocations.

Table 1: List of questionnaire items employed for the analysis

Category	IEQ items	Survey questions	Rating scale
Thermal comfort	Thermal satisfaction	I am satisfied with the thermal conditions in my office workspace.	1--5
Visual comfort	Quality of light	I am satisfied with the QUALITY of light in my office workspace.	1--5
	Access to daylight	I am satisfied with ACCESS to natural daylight in my office workspace.	1--5
	View	I am satisfied with the VIEW from my office.	1--5
Ability to Control	Temperature	I am satisfied with the ABILITY to alter the temperature in my office workspace.	1--5
	Electric lighting	I am satisfied with the ABILITY to alter the electric lighting to meet my needs.	1--5
	Blinds and daylight	I am satisfied with the ABILITY to alter the blinds and daylight source to meet my needs.	1--5
Source of dissatisfaction	Temperature condition	In general, how satisfied are you with the temperature in the workspace where you spend the most time?	1--5
	Too cool	Generally, I am TOO COOL in my office workspace.	1--5
	Too warm	Generally, I am TOO WARM in my office workspace.	1--5
	Lighting condition	In general, how satisfied are you with the overall lighting conditions in the workspace where you spend the most time?	1--5
	Too bright in the morning	I find my workspace too bright in the morning.	1--5
	Too bright in the afternoon	I find my workspace too bright in the afternoon.	1--5
	Too dark in the evening	I find my workspace too dark in the evening	1--5
	Glare	My computer screen has a glare on it	1--5
	Unnecessary lighting	I feel as though there is unnecessary lighting in my workspace.	1--5

This study was performed in August in three office buildings located in North Carolina and Virginia. All of the buildings in the current dataset were serviced by centralized HVAC systems and in some levels equipped with Under-floor Air Distribution System (UFAD). From 5031 questionnaires, a total of 1026 individual responses were obtained with the average response rate (i.e. number of completed questionnaires divided by number of email invitations sent) of 20%. Survey respondents' personal characteristics such as age (20 or below, 21-30, 31-40, 41-50, and 51 or above), gender (male and female), and work characteristics (type of work, time spent at workspace) are described in Table 2. The

majority of the participants were in open-plan office layouts (87.4%) compare with enclosed office. 31% of participants have age range between 41 and 50 years, 54.4% engaged in a typing or reading role (40.7%), and 51.8% worked in the same workspace between 1 and 5 years. The office layouts were classified into four categories: (1) Enclosed private office (private and shared with other people) (2) Open office (cubicles with high partitions), (3) Open office (cubicles with low partitions), and (4) Open office with no partitions. The workspace characteristics (office layouts) and the number of survey samples within each office layout category are listed in Table 3. Among the different configurations of open-plan offices, low-partitioned cubicle is the single most popular office configuration (54.3% of the total occupants). A small fraction of the survey respondents occupied private offices and shared single-room offices (11.5%).

Table 2: Characteristics of the respondent samples (total n=1026).

Personal characteristics	Description	Sample size (n)	Percentage (%)
Gender	Female	511	49.8
	Male	511	49.8
	Unknown	4	0.4
Age	20 or below	6	0.6
	21-30	145	14.1
	31-40	284	27.7
	41-50	318	31.0
	51 or above	252	24.6
	I prefer not to answer	21	2.0
	Work category (type of work group)	Reading, seated	418
Writing		23	2.2
Typing		558	54.4
Filling, seated		3	0.3
Filling, standing		6	0.6
Walking		17	1.7
Lifting/packing		1	0.1
Time of working in workspace occupied	Less than 1 year	432	42.1
	1-5 years	531	51.8
	5+ years	63	6.1

Table 3: Number of survey responses in different office layouts

Office layout	Number	Percentage (%)
Enclosed Office: private and shared with other people	118	11.5
Open Office: cubicles with high partitions (5 feet or higher)	181	17.6
Open Office: cubicles with low partitions (lower than 5 feet)	557	54.3
Open Office: workspace in open office with no partitions	159	15.5
Other	11	1.1
Total	1026	100

1.2. Data analysis

Regarding the data, analysis measures have been taken. First, the mean satisfaction level of each IEQ factor (Table 2), except category of source of dissatisfaction, in four different office layouts was investigated. Also, the percentage of dissatisfied occupants who voted 1 and 2 on the five-point scale was estimated. This average shows the number of potential complaints in comfort studies. Second, separating those who were significantly dissatisfied assessed the importance level of dissatisfaction for each subcategory on lighting condition and thermal condition, which is done by analyzing IEQ factors under category “source of dissatisfaction”. For this purpose, the number of occupants falling into score 1 and 2 were counted. The influence of each subcategory was examined in all office layouts in order to find out the most influential factor on lighting and thermal dissatisfaction. Third, multiple regression analysis was used to predict the level of effectiveness of various IEQ factors in relation to the occupants’ overall assessment on their workspace. For this purpose, 7 IEQ factors under thermal comfort, visual comfort, and the ability to control in Table 1 were considered as independent variables and the overall satisfaction was considered as the dependent variable. Therefore, the relative importance of the 7 IEQ factors can be estimated by regression coefficients to determine overall satisfaction in different office layouts.

2.0 RESULTS

2.1. Occupant satisfaction with different aspects of IEQ

Figure 1 compares the average score of occupants’ overall satisfaction of the IEQ questionnaire items based on the five-point scale from very dissatisfied (1) to very satisfied (5) in four different office layouts. Closer inspection of the graph shows almost all IEQ factors in visual and thermal comfort categories achieved the satisfaction rated higher than neutral level by occupants in different office layouts. In contrast, occupants in all office layouts were dissatisfied with all IEQ factors in ability to control. Among 7 IEQ factors in Table 1, satisfaction with ‘quality of light’ received the highest overall workspace score in all four different office layouts. On the other hand, ability to alter the temperature received the lowest satisfaction score from occupants in all different office layouts. In terms of visual comfort, open-offices with low partitions outscored the other office layouts across ‘view’ and ‘natural light’. Also it is registered as the second highest satisfaction score for ‘quality of light’. Open-offices with high partitions received the lowest overall satisfaction score in almost all IEQ factors, except ‘view’. Interestingly, the noticeable differences between open-plan offices with low partitions and open-plan offices with high partitions appeared in ‘access to natural light’ and ‘view’. Between open-plan offices, satisfaction with ‘quality of light’ and ‘thermal condition’ increased as the height of partitions decreased. Satisfaction with all IEQ factors in the category of ability to control was almost similar in for open-plan offices. In general, open-plan offices with high partitions reported the lowest occupant satisfaction across 6 out of 7 of the IEQ factors. In all four layouts, occupants expressed slight satisfaction with ‘quality of light’, while ‘thermal condition’ and ‘ability to alter the blinds and daylight’ were more neutral.

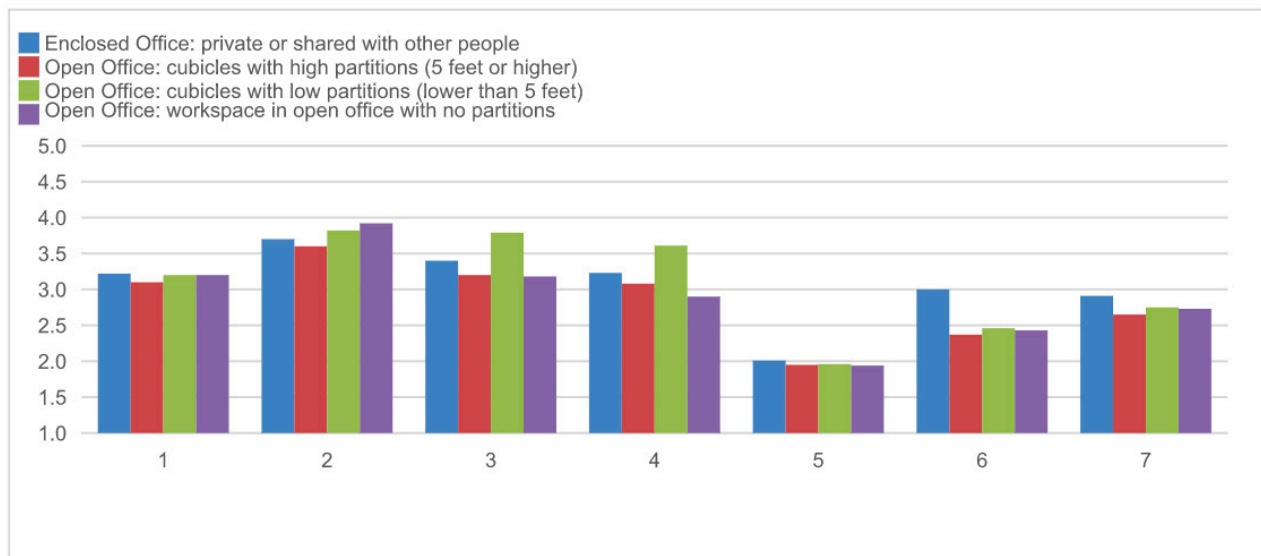


Figure 1: Mean satisfaction rating (1 = very dissatisfied, through 3 = neutral to 5 = very satisfied) for IEQ questionnaire items by office layout configurations.

Survey respondents who fell into the lowest two points (1 and 2) on the five-point satisfaction scale counted as the percentage of dissatisfied. The percentage of dissatisfied with each IEQ factor was shown in Fig. 2. In general, the most interesting aspect of this graph was the low dissatisfaction rates of most IEQ factors in all four different office layouts. Enclosed offices showed lower dissatisfaction rates than open-plan offices (except for ‘visual comfort’) while

no significant differences were found between different office layouts. Open-plan offices with low partitions were reported at almost the lowest level of dissatisfaction among three open-plan configurations across all IEQ factors except for 'quality of light' and 'thermal condition'. In addition, occupants in open-plan offices with low partition were more satisfied across all IEQ factors compare to open-offices with high partition. On the other hand, the highest levels of IEQ dissatisfaction were recorded in 'ability to alter temperature' which is considerably higher than other IEQ factors. More than half of the occupants in enclosed offices and about 60% of occupants in open-offices with no partitions reported dissatisfaction with this factor. The percentage of dissatisfaction for occupants of open-plans with high partitions was relatively higher than other open-office layouts in IEQ factors under categories of visual and thermal comfort.

Fig 3a and 3b compared the relative importance of different factors and their influence on thermal and lighting dissatisfaction in four office layouts. A number of factors reported by occupants were identified to address the most influential factor on lighting and thermal dissatisfaction. Further analysis showed that no significant differences were found between different IEQ factors in terms of lighting dissatisfaction. The major source of lighting dissatisfaction in open-offices with low partitions were 'unnecessary lighting in workspace', followed by 'workspace too bright in the morning'. In terms of thermal dissatisfaction, occupants in all types of office layouts tend to be more dissatisfied with 'too cool workspace' rather than 'too warm'. Dissatisfaction with 'too cool workspace' was almost doubled compared to 'too warm workspace' in all office layouts.

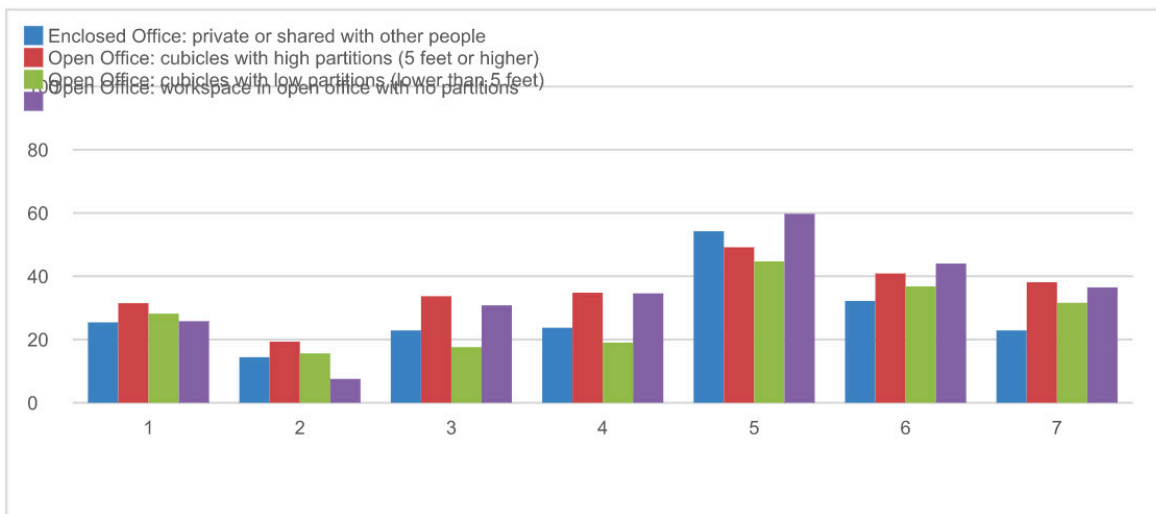


Figure 2: Percentage of Dissatisfied for IEQ questionnaire items by office layout configurations

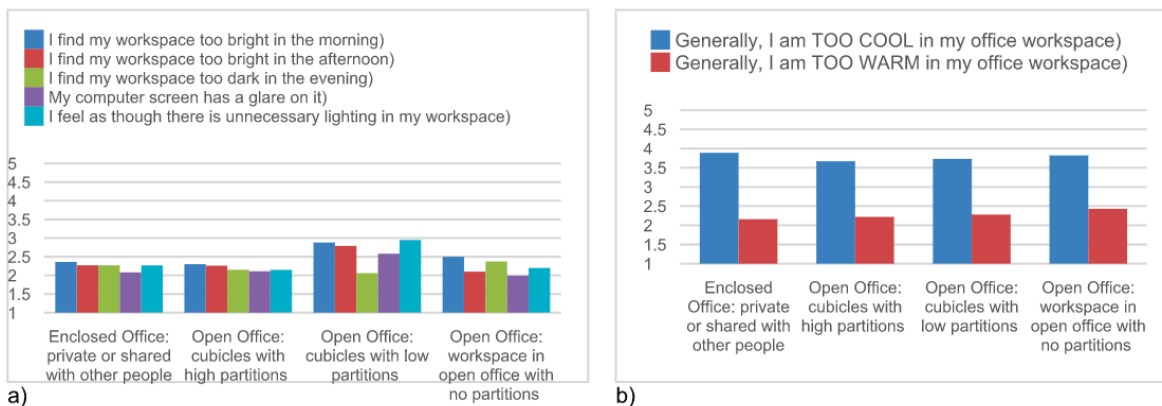


Figure 3: Source of dissatisfaction of a) lighting and b) temperature in different office layouts

2.2. Relative importance of different IEQ factors

Multiple regression analysis was examined separately on survey responses from the layouts to determine how the relative importance of different IEQ factors changes under the different spatial configurations. The four regression models explain the variance in outcome variables for both genders between 38% and 47%. As Table 4 illustrates, the regression coefficient is used to examine the importance of individual IEQ factors' and the influence they have on the

occupants' satisfaction. Although insignificant regression coefficients are presented in the charts and the table, they are excluded from the analysis. Based on Table 4, a radar chart was created to visualize the various IEQ priorities of the four office layouts in Fig. 4 (included both significant and insignificant regression coefficients). For both gender, 'quality of light' (b = 0.21 for enclosed offices), 'view' (b = 0.25 for open-office high partitions and b = 0.25 for open-office with no partitions), and 'thermal satisfaction' (b = 0.24 for open-office with low partitions) have the strongest relationship with occupants' overall satisfaction (Fig. 4). However, the relative importance of 'view', 'thermal condition' and 'quality of light' varied between the different office layouts. While view ranked as the most important factor for occupants in open-offices with high partitions (b = 0.25), it appeared as the least important factor in enclosed offices (b = 0.15). Thermal condition had a relatively higher impact on open-offices with low partitions (b = 0.24) and open-offices with no partitions (b = 0.21) on occupants' overall satisfaction. That indicated that its relative importance to the overall office satisfaction decreased as the height of partitions in open-offices reduced. Similarly, thermal condition was more important for those in open-plan offices with low partitions than occupants in other office layouts. Quality of light had a bigger impact on occupants' overall satisfaction in open-plan offices with low partitions than open-plan offices with no partitions.

Fig. 5 was created to visually compare the importance of various IEQ factors in different office layouts on overall satisfaction between different ages, genders, types of work, and time spent in the workspace. Although Fig. 5 illustrates both significant and insignificant regression coefficients, only significant ones are analyzed and reported. As shown in Fig. 5a and 5b, there are a number of remarkable differences between IEQ factors and their influence on female and male overall satisfaction. 'Thermal condition' factor had the highest influence on female overall satisfaction in enclosed offices (b = 0.32) followed by open-offices with low partitions (b = 0.30). However, this was the least influential factor on male overall satisfaction. View, quality of light, and access to natural light had the highest impact on male overall satisfaction. Moreover, 'view' had the biggest impact on male occupant overall satisfaction in open-plan offices with no partitions (b = 0.31). In the other words, thermal comfort was the most significant issue for females' overall satisfaction; However, visual comfort had the most influence on males' overall satisfaction.

Table 4: Implicit importance (estimated by regression coefficients) of 7 IEQ factors in relation to occupant overall workspace satisfaction for both genders

Predictor	Regression coefficients (b)			
	Enclosed Office: private or shared with other people (R2 = 0.46)	Open Office: cubicles with high partitions (R2 = 0.38)	Open Office: cubicles with low partitions (R2 = 0.47)	Open Office: workspace in open office with no partitions (R2 = 0.45)
Satisfy with the thermal conditions	0.16**	0.14**	0.24**	0.21**
Satisfy with the quality of light	0.21**	0.10	0.22**	0.18**
Satisfy with access to natural daylight	0.07	0.06	0.14**	0.10
Satisfy with the view	0.15*	0.25**	0.16**	0.25**
Satisfy with the ability to alter the temperature	0.01	0.01	-0.06	0.10
Satisfy with the ability to alter the electric lighting	0.00	0.10	0.01	-0.09
Satisfy with the ability to alter the blinds and daylight	0.16*	0.11	0.08*	0.03

Note: Dependent variable: Overall satisfaction with workspace. Significance level: **P < 0.01, *P < 0.05.

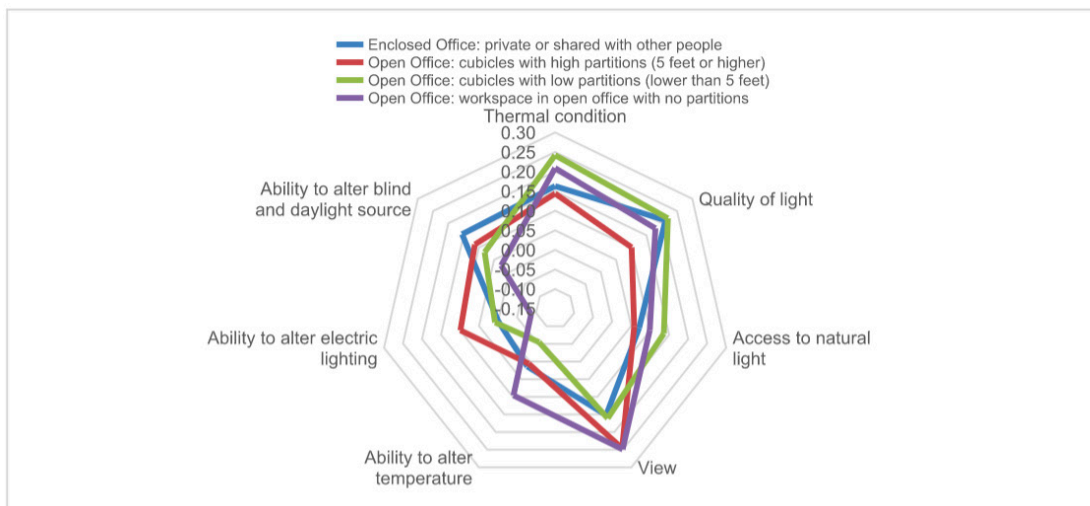


Figure 4: Relative importance of IEQ factors estimated by regression coefficients in four different office layouts for both genders

Fig. 5c, 5d, 5e, and 5f show the relative importance of 7 IEQ factors in relation to the occupants' overall satisfaction between four different age groups and their workspace. The relative importance of all IEQ factors varied between the different age groups in four office layouts. In general, among all IEQ factors, 'view', 'quality of light', and 'access to natural light' showed the strongest relationship with occupants' overall satisfaction within various age groups. In open-offices with no partitions, 'thermal condition' (age 21-30) 'view' (age 31-40 and 51 or above) had the highest influence on occupants' overall satisfaction. Interestingly, in open-plan offices with high partitions, 'view' was the most influential factors on overall satisfaction of occupants between the age of 21 and 50. The factor of 'thermal condition' was strongly related to overall satisfaction of occupants between the age of 31 and 50 in open-plan offices with low partitions compared to the other office layouts. As mentioned in section 2, the majority of occupants engaged in reading and typing in various office layouts. Further analysis between the two types of the work in all four office layouts indicated that although 'thermal condition' had the highest impact on occupants' overall satisfaction for typing, 'quality of light' was the most influential factor for reading (Fig. 5g and 5h).

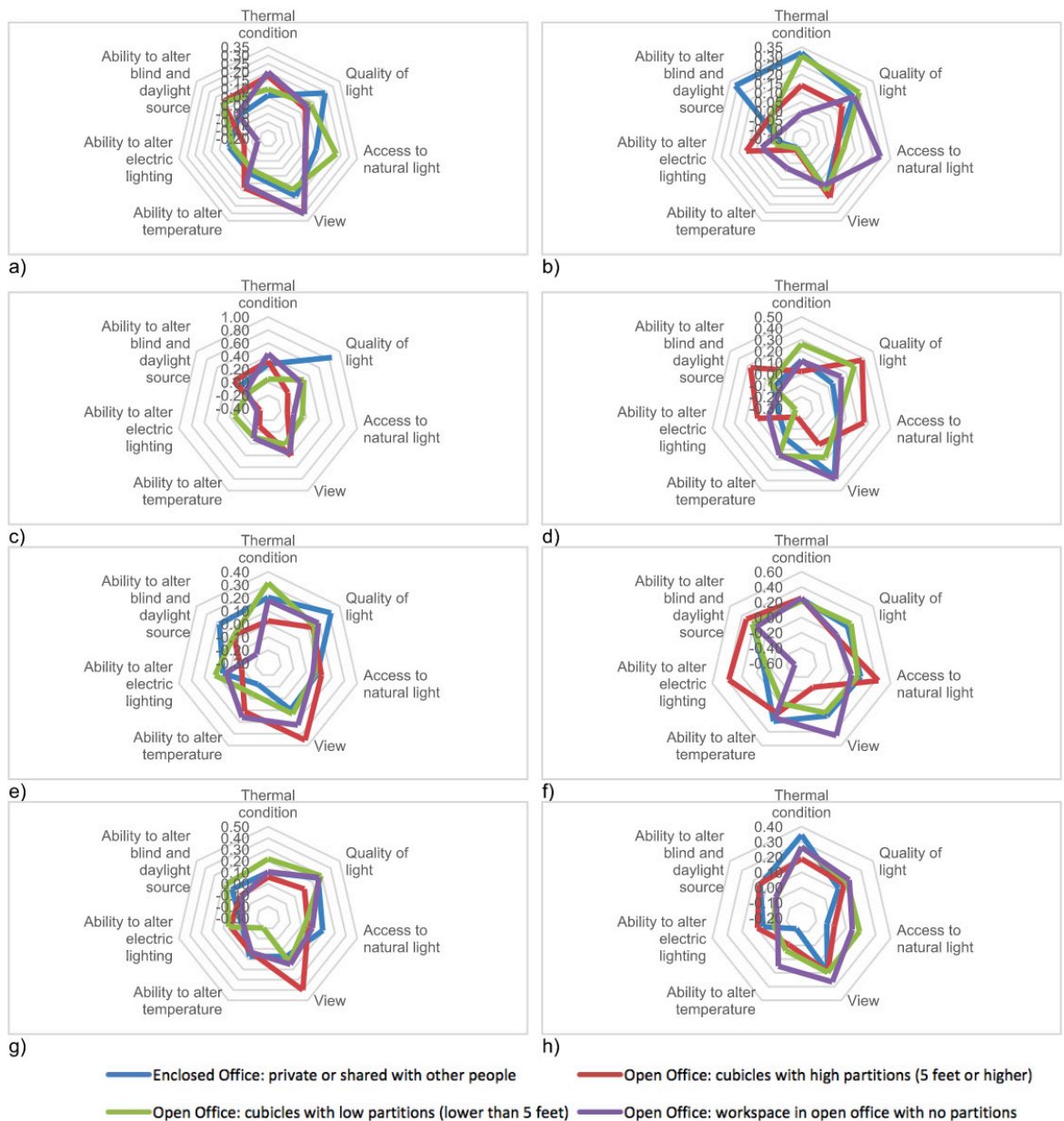


Figure 5: Relative importance of IEQ factors estimated by regression coefficients in four different office layouts for a) male, b) female, c) age (21-30), d) age (31-40), e) age (41-50), f) age 51 or above, g) type of work (reading, seated), h) type of work (typing).

DISCUSSION AND CONCLUSION

Overall, this study identified that occupants' responses on different IEQ factors varied among office layouts (enclosed private and shared, open office with high partitions, open office with low partitions, and open office with no partitions). According to Fig. 1 and Fig. 2, occupants in open-office with low partitions were remarkably more satisfied with visual comfort (except 'quality of light') than occupants in the other three office layouts. In contrast, open-offices with high partitions received the lowest mean satisfaction score and highest percentage of dissatisfaction in almost all visual comfort factors except 'view'. This is because of the lower partitions are, there is more access to light. In the other words, it seems that the height of partition can contribute to better visual satisfaction. Between open-plan offices, satisfaction with 'quality of light' and 'thermal condition' slightly increased as the height of partitions decreased. Even though the mean score for all IEQ factors under the categories of visual comfort and thermal comfort were slightly above the neutral line on the satisfaction scale, all IEQ factors in the category of ability to control were mostly rated as dissatisfaction. Further analysis showed that feeling too cool in the workspace was the main cause of occupants' thermal dissatisfaction. The level of importance of different IEQ factors inferred by multiple regression models revealed that the impact of 'quality of light', 'view', and 'thermal satisfaction' had on overall satisfaction were relatively large. One of the

goals for designing open-plan offices is to introduce more light in the workspace so open office occupants tend to have more sufficient light than those in enclosed or private offices. The results indicated that 'view' had a highest impact on occupants' satisfaction in open-plan offices with no partitions and open-offices with high partitions compare to other offices. This similarity between open offices with no and high partitions in terms of 'view' was because open-offices with high partitions are located near the windows. For this reason, open-offices with high partitions had a better access to views than other types of open-plan offices. This study has identified that the relative importance of thermal condition to overall office satisfaction increased as the height of partitions in open-offices decreased. Relative importance of occupants' overall satisfaction differs not only by gender but also in how long they are working in the building. We found notable differences between the magnitude and the type of individual IEQ factors influence on female and male overall satisfaction. Thus, thermal comfort tends to have greater influence on female overall satisfaction than male. The relative importance of visual comfort on male overall satisfaction was higher than females. These results are in line with previous studies (Choi, Aziz, and Loftness 2010). For example, in open-offices with low partitions 'thermal condition' had the highest influence on female overall satisfaction ($b = 0.30$) but it was the least influential factor on male overall satisfaction ($b = 0.10$) as access to natural daylight had the highest impact on males. It supports the literature that females are more sensitive to thermal conditions than males. In terms of work category 'thermal condition' had a higher influence on occupant satisfaction for those who mostly typed, but 'quality of light' was the most influential factor for those who mostly read. Interestingly, 'access to natural daylight' and 'view', which were the most influential factors between genders and age group, had the lowest impact on the work category. This study provides valuable information on the effect of different office layouts on overall occupant satisfaction in terms of various IEQ factors. The findings of this study could enhance our understanding of the importance that various IEQ factors have among occupants in office layouts.

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