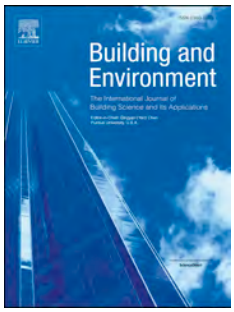

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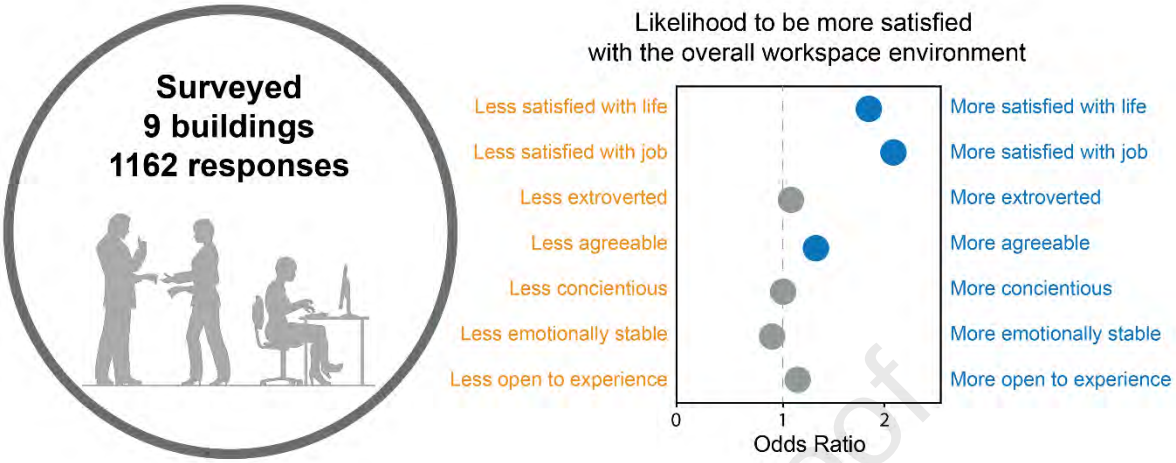
Graphic Abstract



Impacts of life satisfaction, job satisfaction and the Big Five personality traits on satisfaction with the indoor environment

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Abstract

Providing indoor environmental quality (IEQ) that satisfies building occupants is an essential component for sustainable and healthy buildings. Existing studies mainly analyse the importance of environmental factors on occupant satisfaction, but often overlook the influence of personal factors. Here, we aim to explore the influence of personal factors like life satisfaction, job satisfaction, the Big Five personality traits, sex, and age on occupant IEQ satisfaction. We conducted a cross-sectional assessment in nine air-conditioned commercial buildings in Singapore and surveyed 1162 individuals on their satisfaction with 18 IEQ parameters. Using proportional odds ordinal logistic regression we found that occupants with higher job and life satisfactions were, respectively, 1.3 – 2.3 and 1.3 – 2 times more likely satisfied with the 18 IEQ parameters. The odds ratios (OR) for overall environment satisfaction and job and life satisfaction were 2.1 (95% CI: 1.8 – 2.6) and 1.9 (95% CI: 1.6 – 2.3). We speculate that occupants' satisfaction with their job and the overall environment are entwined, meaning that better workspace could improve job satisfaction and vice versa. We observed some associations between the Big Five personality traits and some IEQ parameters, but the corresponding effects were small. Due to the substantial relationship between job and overall workspace satisfaction observed in this study, we recommend including job satisfaction questions in future post occupancy evaluations (POEs).

Keywords: Indoor Environmental Quality (IEQ), Job Satisfaction, Life Satisfaction, Post Occupancy Evaluation (POE), Big Five Personality Traits

1 Introduction

A building's success is often determined by how well indoor environmental quality (IEQ) supports the occupants within it. This type of success typically is measured by assessing how satisfied occupants are with distinct elements of their environment or the overall space [1,2]. For example, perceptions of thermal comfort, lighting, air quality and acoustics are known to influence overall environmental satisfaction [3–7]. And these perceptions can be tied to measurable physical parameters (e.g., temperature, illuminance, carbon dioxide concentration and sound pressure levels). For instance, architectural parameters such as office type, spatial layout, desk location (distance from window), window view, amount of available space, comfort of one's furnishings, space cleanliness, façade design, window to wall ratio and building orientation also show a strong relationship in predicting environmental satisfaction [8–12]. In addition to being able to tie perceptions to physical features, the literature shows perceptions can also be tied to some personal factors (such as metabolic rate). Thermal comfort for instance, is often related to four physical parameters (air temperature, mean radiant temperature, air speed, and relative humidity), and two personal characteristics (clothing insulation and metabolic rate) [13].

Though findings have been inconsistent and sometimes small, age and sex have also been shown to have an impact on occupants' satisfaction with office IEQ, specifically with regards to sex and age, [12,14–16]. But if physiological differences (i.e., sex and age) can play an important role in occupants' satisfaction, other individual differences may also be important. People have different expectations, perceptions and reactions to the indoor environment. For example, we know occupants' perceptions can influence each another; overall environmental satisfaction is affected by a person's satisfaction with other IEQ parameters, such as cleanliness and amount of space [9,17]. There is also evidence showing that symptoms, like those common to sick building syndrome (SBS) relate to occupants' satisfaction with the physical environment [18]. However, not all self-reported factors are helpful in environmental satisfaction prediction. Some studies have suggested that occupants' past experience and expectations may influence perceptions of the indoor environment [19,20] (e.g., subject's assumption to a green standard certified building), but these factors are difficult to translate into quantifiable metrics. Furthermore, it is challenging to draw conclusions about seemingly influential, yet dynamic personal factors (like emotion or mood) that tend to shift continuously.

One human factor possibly subject to fluctuation that has consistently shown to have a positive relationship with environmental satisfaction is job satisfaction [21–24]. This relationship is linked to important outcomes for employers such as job stress [25], employee benefits and salary [26], physical and mental well-being [27], and satisfaction with management [22]. This relationship also appears to be linked with age—in general job satisfaction tends to improve as we get older [28]. Further, work like the Cost-effective Open-Plan Environments (COPE) project showed that higher overall environment satisfaction enhances job satisfaction [22,29]. We speculate that the job – environment satisfaction relationship can also be explain in an alternative direction. For example, staff who are more satisfied with their workspace environment (i.e., fewer complaints or higher tolerance) might in turn be more satisfied with their job.

Though complex and dynamic characteristics like those mentioned above may prove challenging to pinpoint, how might more static or stable characteristics like life satisfaction or

personality influence perceptions? Life satisfaction has been linked to significant life and personal outcomes such as marriage and job stability and satisfaction [30,31], life events and experiences [32], overall happiness [33] and even personality [34]. There is evidence showing life satisfaction also may be linked to environmental perceptions. For example, in one study, poor air quality and high workplace noise levels appeared to markedly diminished life satisfaction [35]. This work raises the question—would higher life satisfaction in occupants allow for a higher tolerance (i.e., more satisfaction) with the surrounding environment? Unfortunately the life – environment quality satisfaction relationship currently remains vastly unexplored.

Like life satisfaction, personality has also been linked to a wide range of significant life outcomes including health, relationship quality, job satisfaction, job selection, culture and even performance [36–39]. There are a few studies that investigate the relationship between personality and occupants' satisfaction with IEQ in workspaces. For example, a study of 389 occupants in five offices reported more extraverted and more agreeable workers were in general more satisfied with the physical environment in open plan offices [40]. In another study surveying 190 respondents in 17 multi-tenant offices results showed those people higher in Extraversion, Openness to experience and Agreeableness also have higher satisfaction with the overall office environment [41]. Similarly, in a study of 327 employees within 13 organizations, a small but significant effect was found between personality traits and environmental satisfaction [42]. A laboratory test on 180 occupants also found personality to have an indirect influence on people's satisfaction with more abstract IEQ factors (i.e., views from window, level of control and privacy) [43]. And interestingly, a longitudinal study following 19 occupants for three to seven months shows that those higher in Extraversion were more likely to be stressed by workspace IEQ [44]. With variables like personality, a larger sample size is often desired to understand generalizability and true effect, therefore studies like these mentioned above have limitations. However, they do offer some valuable insights into this relatively unexplored domain.

Using our knowledge of these psychological characteristics (personality, life and job satisfaction) along with the literature, we have developed a conceptual model to begin exploring the connections between these variables and environmental factors (Figure 1). The model suggests that the overall environmental satisfaction in the workspace is affected by satisfaction with other individual environment features, physiological personal factors (age and sex), and psychological personal factors (satisfaction with life, job and the Big Five personality traits). Other factors in lighter grey box are considered to be potential variables that may have an impact to overall environmental satisfaction via satisfaction with environmental features and personal factors. Despite an association found between life satisfaction and personality traits, results from four large scale independent surveys suggested that personality variables could only explain 0.1 – 1.8% of the variance of overall life satisfaction [45]. Participants' life satisfaction and personality traits are assumed to be independent variables in the current study. Past work shows the relationship between life and job satisfaction to be highly correlated and bi-directional [31], therefore, within our model, their impact to the overall environment satisfaction is separately determined.

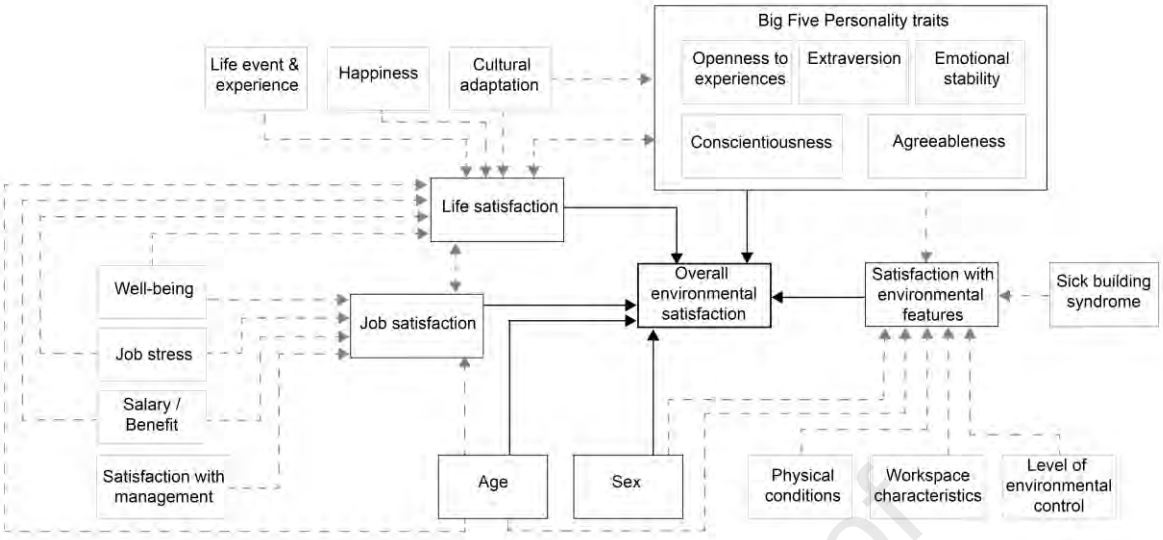

Figure 1 Conceptual model between overall environmental satisfaction and related variables.

This study aims to evaluate the impacts of psychological personal factors, specifically life satisfaction, job satisfaction, and the Big Five personality traits, on occupants' satisfaction with indoor environmental parameters in workspaces. Participants' age and sex are collected as control parameters in the analysis.

2 Methodology

2.1 Sampling scope

Nine Green Mark certified, air-conditioned, office buildings in Singapore were surveyed resulting in 1162 individual responses. To maintain consistency, our participants only included staff who were performing office work and had personal workstations, and excluded any individuals working within any non-office spaces within the same building. In each building, at least 10 % of the total occupancy were surveyed. We provided an individual survey link for each building, and the facility management team for each space distributed this link to all target occupants. This study is approved by the Office for Protection of Human Subjects from University of California Berkeley. The surveyed database with anonymized data is openly and freely available online [46].

2.2 Survey parameters

In this study, we collected self-reports of occupants' (i) satisfaction with their workspace environment, (ii) demographics, (iii) life satisfaction, (iv) job satisfaction, and (v) Big Five personality traits.

2.2.1 Environment satisfaction

To assess satisfaction with the workspace environment, we surveyed 18 IEQ parameters including temperature, humidity, air movement, flexibility of dress code, electrical lighting, natural lighting, glare, views from windows, stuffiness, odours, noise level, sound privacy, cleanliness, available space, furnishings, level of personal control, overall privacy and overall environment. Each satisfaction question starts with: "How satisfied are you with the …" followed by the environmental factors in question. We used a 7-point Likert scale: "very satisfied" (+3), "satisfied" (+2), "somewhat satisfied" (+1), "neither satisfied nor dissatisfied" (0), "somewhat dissatisfied" (-1), "dissatisfied" (-2), and "very dissatisfied" (-3).

2.2.2 Demographics

The questionnaire also asked participants to report their sex (male or female) and age group (21 – 30, 31 – 40, 41 – 50, 51 – 60, and 61 or above).

2.2.3 Life satisfaction

The satisfaction with life scale (SWLS) was used to assess occupants' life satisfaction [47]. This tool is widely used within the social sciences as a measure of the life satisfaction component of subjective well-being. The sale has high internal consistency and good test-retest reliability [48]. There are 5 related questions in this tool as shown in Appendix Figure A1. This scale also uses a 7-point Likert scale: "Strongly agree" (7), "Agree" (6), "Somewhat agree" (5), "Neither agree nor disagree" (4), "Somewhat disagree" (3), "Disagree" (2), and "Strongly disagree" (1). To generate a score for each participant, responses of these 5 questions were averaged. An occupant with a higher score on the SWLS indicates that they are more satisfied with their life.

2.2.4 Job satisfaction

Participant job satisfaction could be a multi-directional index [23]. However, to limit survey fatigue and cognitive load on participants we reduced this to a single-item measure with a scale that mimicked the last item on the SWLS. The item asked: "Taking everything into consideration, I am satisfied with my job as a whole" We used the same 7-point Likert scale for SWLS in this question. Higher scores in job satisfaction indicates that a person is more satisfied.

2.2.5 Big Five personality traits

We operationalized personality utilizing the Five Factor Model (FFM) [49] which defines one's consistent thoughts, feelings, and behaviours in terms of traits—also known as the "Big Five" personality traits. Within this framework it is believed that each individual possess a unique level of each trait: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness to Experience [49]. Each of these traits are assessed on a continuum and are also comprised of a number of "facets", or sub-traits that help define them. Those high in Extraversion are talkative, assertive, sociable and sensation seeking. Those high in Agreeableness tend to be warm, trusting, altruistic and compassionate. Those high in Conscientiousness are dutiful, reliable, self-disciplined, and organized. Individuals high in Emotional Stability are unflappable, not easily anxious or depresses, and are secure. And people high in Openness to Experience are usually characterized as creative, imaginative, intellectually curious, and comfortable with abstract thoughts and ideas.

In the current study, we focus our assessment on the high level traits rather than the facets and do so using the Ten Item Personality Inventory (TIPI) [50]. (See Appendix Figure A2). The TIPI is a widely used and validated short measure of the Big Five intended to reduce participant fatigue and cognitive load. Also, it demonstrates high convergence with other longer measures of personality [50]. Each of the five personality factors is measured with two items aimed at capturing the polarity of each trait. For example, the trait Emotional Stability (i.e., Neuroticism) is measured with two items: (i) Clam, emotionally stable and (ii) Anxious, easily upset. In the case of Emotional Stability, the second item is reversed scored, and then the two items are averaged for a final "Emotional Stability Score". Those high in Emotional Stability will have a higher score, and those lower in Emotional Stability (i.e., high in Neuroticism) will have a lower score. Before each item, the participant sees the statement "I

see myself as…:", and reports whether or not they strongly disagree or strongly agree with the statement. The scale reflects a 7-point Likert scale, with scale points similar to that of the SWLS and job satisfaction item.

2.3 Statistical analysis

2.3.1 Correlations between parameters

Applying the spearman rho (ρ) approach, we evaluated the correlation coefficient between satisfaction with the 18 IEQ parameters and the other personal variables: (i) job satisfaction, (ii) life satisfaction, and (iii) the Big Five personality traits. The correlation coefficient is considered statistically significant when the corresponding p-value < 0.05.

2.3.2 Proportional odds ordinal logistic regressions

We applied proportional odds ordinal logistic regressions to identify which personal factors (i.e., life satisfaction, job satisfaction, Big Five personality traits, sex, and age) have higher influence on the 18 IEQ satisfaction parameters. For life satisfaction, job satisfaction and the Big Five personality traits, we used the scores resulting from the SWLS, a 7-point job satisfaction item and the TIPI as the numeric inputs. For sex, the "female" factor acted as the base case and "male" as the alternative case. For participant age, we took the median year value to represent each age group. For example in the "21 – 30" age group and the "31 – 40" gage group the representing years were 25 and 35 year old respectively. The age inputs in the regression analysis were further normalized by 10, meaning, one-step of sensitivity change in age group was 10 years instead of 1 year. Occupant satisfaction responses on the 7-point Likert scale in each of the 18 IEQ parameters were the dependent variables in terms of factors (e.g., Satisfied, Very dissatisfied).

An odds ratio (OR) is used to measure the association between a predictor and the dependent variable [51]. For example, when examining "life satisfaction" with "temperature satisfaction", if an odds ratio of 2 is found, we know that for a one-unit increase in a life satisfaction score (e.g. 1.5 to 2.5) leads to a 2 fold increase in the odds of a one-scale temperature satisfaction increase (e.g., Somewhat satisfied to Satisfied). In addition, the above interpretation is based on an assumption that all other variables within the same analysis remain unchanged. In other-words the two participants (one's life satisfaction score = 1.5 and the others score = 2.5) being compared are both extroverted, satisfied with their job, the same sex and from the same age group. Analysis using ORs provides direct insight into the strength of the relationship between the predictor and dependent variable. It also allows us to compare the magnitude of the odds (i.e., likelihood of the impacts) between predictors to the output. In short, a higher OR means higher impact from a personal factor to the IEQ satisfaction parameter. These analyses were performed in R version 4.1.1 [52]. We used the "polr" function in "MASS" package to develop the logistic regression model [53].

3 Results

A total of 1162 occupants were surveyed in 9 air-conditioned office buildings in this study. Within the database, 626 (54 %) of respondents were female and 496 (43 %) were male, while the remaining 3 % did not specified. 254 participants (22 %) reported being 21 – 30 years of age, 401 (35 %) reported being 31 – 40, 290 (25 %) were 41 – 50, 145 (12 %) were 51 – 60, and 31 (3 %) were 61 years or older. 41 participants chose not to report their age. The survey sample and the percentage of the sampling rate (in bracket) for Buildings 1 – 9

are: B1 215 (22 %), B2 70 (78 %), B3 65 (85 %), B4 82 (63 %), B5 108 (13 %), B6 17 (94 %), B7 108 (15 %), B8 351 (23 %), and B9 146 (39 %).

3.1 Distribution of IEQ satisfaction

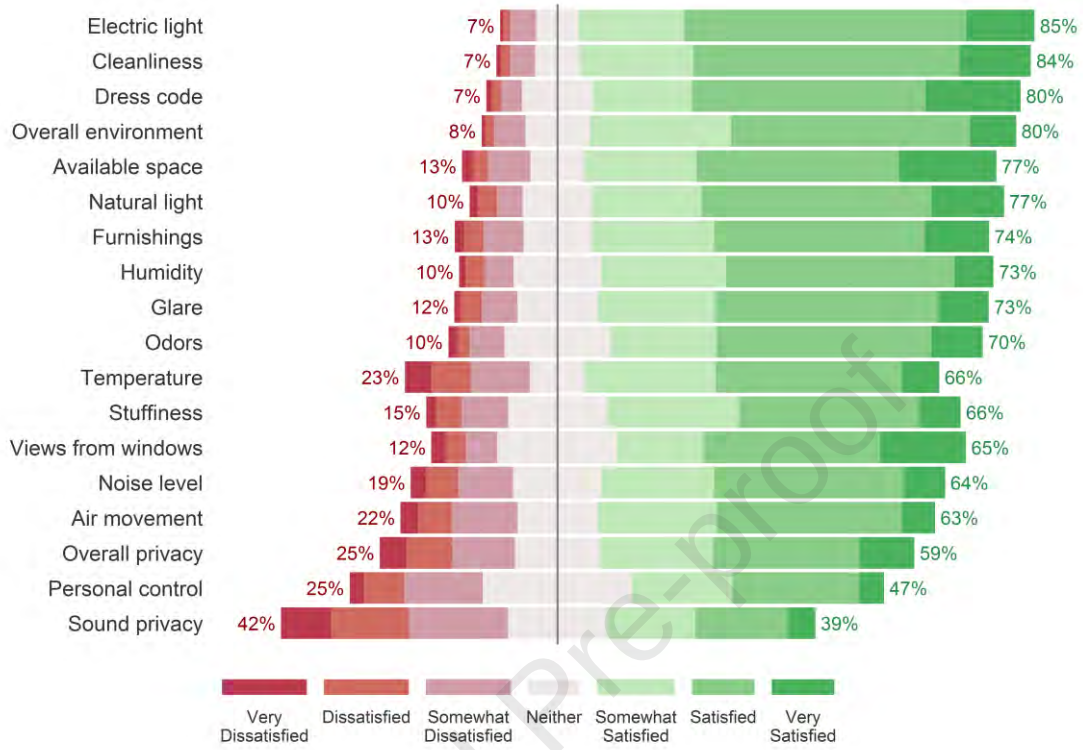

Figure 2 A summary of satisfaction votes for the 18 IEQ parameters. The sequence is arranged from highest satisfaction (top) to lowest satisfaction (bottom). The percentage of satisfied (green) and dissatisfied (red) are reported for each parameter.

Using Cronbach's Alpha (α) with a 95 % Confidence Interval (CI), we evaluated the internal consistence of the IEQ satisfaction subscale consisting of 18 items (α = 0.92, CI: 0.91 – 0.93) [excellent] [54]. The responses for all 18 IEQ satisfaction questions were negatively skewed, meaning that the distribution mean is less than the median (i.e., more observed satisfied responses than dissatisfied responses). The most skewed parameter is satisfaction with electric light (-1.32) and the least skewed parameter is satisfaction with sound privacy (-0.03).

Figure 2 presents a summary of the distribution in satisfaction for each of the 18 IEQ satisfaction parameters surveyed in 9 office buildings in Singapore. The parameters are arranged in descending order of satisfaction. The majority of the parameters (i.e., at least 50 % of the data) fall between 0 "Neither satisfied nor dissatisfied" and 2 "Satisfied", except satisfaction with sound privacy. Building occupants were generally satisfied with the overall workspace environment (% of Satisfaction, $S_{\%}$ = 80 %). We found the three highest satisfied parameters were satisfaction with electric light ($S_{\%}$ = 85 %), cleanliness (84 %) and flexibility of dress code (80 %), while the three highest dissatisfied parameters were satisfaction with sound privacy (% of Dissatisfaction, $D_{\%}$ = 42 %), personal control (25 %) and overall privacy (25 %).

3.2 Distributions of life satisfaction, job satisfaction and Big Five personality traits

Figure 3 shows box plots of the personal factors surveyed: life satisfaction, job satisfaction, Extraversion, Agreeableness, Conscientiousness, Emotional Stability, and Openness to

Experience. Our sample reflected a negative skew (i.e., the median respondent is above the mean value of the scale) of the distribution for most variables. The corresponding skew values are: life satisfaction (-0.71), job satisfaction (-1.48), Extraversion (0.05), Agreeableness (-0.22), Conscientiousness (-0.41), Emotional Stability (-0.56), and Openness to Experience (0.11). 50 % and 75 % of the participants were satisfied with their life (mean [standard deviation] = 4.73 [1.31]) and current job (5.54 [1.06]) respectively. Additionally, on average, participants were higher in Agreeableness (mean [s.d.] = 5.06 [0.94]), Conscientiousness (5.26 [1]), Emotional Stability (5.01 [1.06]), and Openness to Experiences (4.71 [0.91]). Meanwhile, participants were normally distributed with regards to Extraversion around the central score (mean [s.d.] = 3.99 [1.20]).

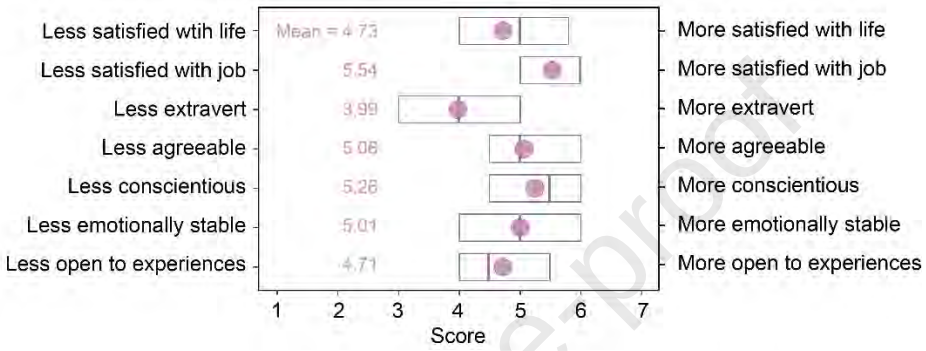

Figure 3 Box plots for the normalized life satisfaction score, job satisfaction score and the Big Five personality traits. The extremities of the boxes are from 25th to 75th percentile of the data. The bold vertical lines indicate the median value and the pink colour dots represent the arithmetic means score for each parameter.

3.3 Correlation analysis

Figure 4 presents the spearman rho correlation coefficients (ρ) of the 18 IEQ satisfaction parameters correlated with life satisfaction, job satisfaction and the Big Five personality traits. We found that job satisfaction has the highest positive correlation with all 18 IEQ satisfaction parameters, meaning that occupants who are more satisfied with their job, are also more likely to be satisfied with the workspace environment, or vice versa, especially with regards to the overall environment (ρ = 0.54), cleanliness (ρ = 0.50), and furnishings (ρ = 0.43). Additionally, life satisfaction was the second most highly correlated variable with all IEQ satisfaction parameters, especially in relation to perceived personal control levels (ρ = 0.37), the overall environment (ρ = 0.36), and cleanliness (ρ = 0.34).

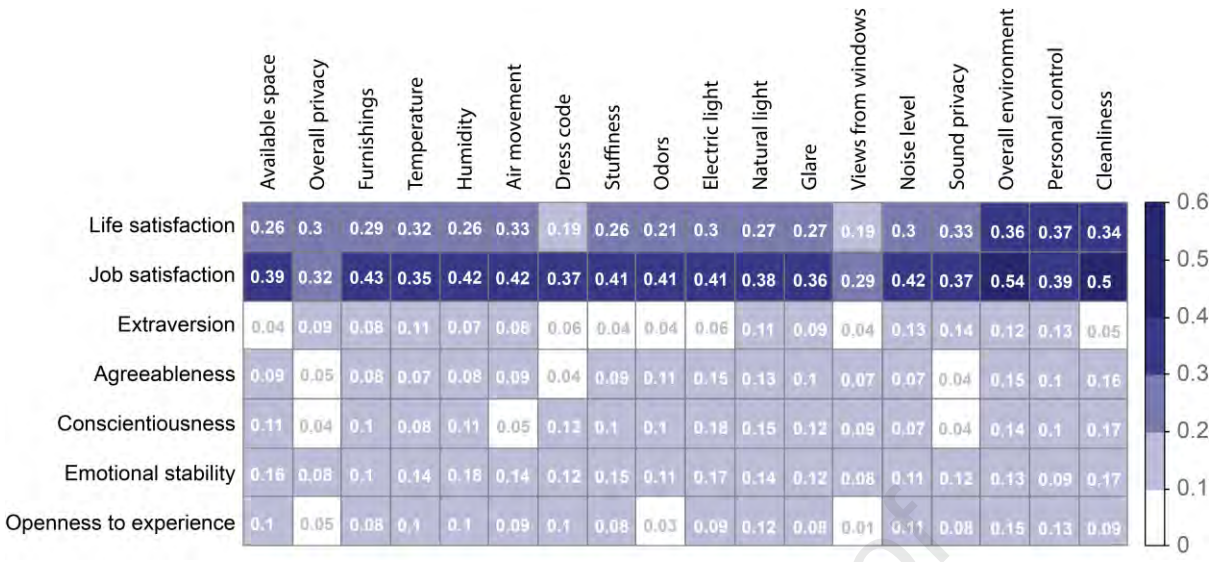

Figure 4 Spearman rho correlation coefficients of 18 IEQ satisfaction parameters in the workspace correlated with life satisfaction, job satisfaction and the Big Five personality traits (Extraversion, Agreeableness, Conscientiousness, Emotional Stability and Openness to Experience). Correlation coefficients with a *p*-value > 0.05 were removed.

When examining personality traits, Emotional Stability was significantly correlated with all 18 IEQ satisfaction parameters, suggesting that the more emotionally stable a person is, the more likely they will be to report higher satisfaction with the workspaces environment—and specifically when it comes to satisfaction with humidity (ρ = 0.18), electric light (ρ = 0.17) and cleanliness (ρ = 0.17). However these correlation coefficients were relatively low (from 0.08 to 0.18) when compared with job satisfaction. Occupants' levels of Agreeableness, Conscientiousness and Openness to Experiences correlate weakly (ρ = 0.08 – 0.17) with most of the IEQ satisfaction parameters. However, there were a few exceptions where correlations were stronger. Specifically, satisfaction with overall privacy, flexibility of dress code and sound privacy was more strongly correlated with Agreeableness; satisfaction with overall privacy, air movement and sound privacy was more strongly correlated with Conscientiousness; and satisfaction with overall privacy, odors and view from the window was more strongly correlated with Openness to Experiences. Extraversion was weakly correlated with even fewer IEQ satisfaction parameters, however, comparatively stronger relationships were found between Extraversion and satisfaction with sound privacy (ρ = 0.14), personal control (ρ = 0.13) and noise level (ρ = 0.13). Lower correlation coefficients are common when examining relationships between the Big Five personality traits and other factors. For example, when examining how personality relates to the specific items in the workspace, significant correlation coefficients were found between 0.21- 0.72 in one study [55] and 0.13 - 0.20 in another study [39]. Though many coefficients reported here are quite low, these should be viewed within the context that little is known within the field as to how these personality traits "typically" relate to environmental satisfaction perceptions like those measured here. Ideally there would be a reference point for how the Big Five relate to outcomes like those measured here [56]. This work however adds to the small but growing literature about relationships between personality and building perceptions.

3.4 Impacts of personal variables on IEQ satisfaction parameters

We further explored the relative impacts of personal factors on each IEQ satisfaction parameter using a proportional odds ordinal logistic regression approach, as seen in Figure 5.

The odds ratio (OR) in the x-axis represents the chance of a one-scale increase in the IEQ satisfaction responses (i.e., somewhat satisfied (+1) to satisfied (+2)) and for a one-unit increase in the personal factors (i.e., life satisfaction score increased from 1 to 2). Further, we assumed a case to be statistically significant if the 95% confidence interval (CI) does not overlap the null value (e.g. OR = 1) [51].

In general, we found that compared to the other personal factors, occupants' job satisfaction (OR: 1.3 – 2.3) has the strongest impact on all 18 IEQ parameters. Its impact was the highest for satisfaction with cleanliness (OR = 2.3, CI: 1.9 – 2.7), overall environment (OR = 2.1, CI: 1.8 – 2.6), and natural light (OR = 1.8, CI: 1.5 – 2.2) — meaning that people who are most satisfied with their job are 2 times more likely to report a one-scale point increase in their satisfaction with the overall environment compared to those who are less satisfied with their job.

The second most important personal factor for all 18 IEQ satisfaction parameters was life satisfaction (OR: 1.3 – 2). Meaning that those participants who are more satisfied with their life, are at least 1.3 times more likely to be satisfied with any of the 18 IEQ satisfaction parameters (compared to those less satisfied with their life). The results showed that life satisfaction has the most impact on satisfaction with sound privacy (OR = 2, CI: 1.7 – 2.4), overall environment (OR = 1.9, CI: 1.6 – 2.3), and overall privacy (OR = 1.8, CI: 1.5 – 2.1).

Our findings showed that none of the Big Five traits yielded an odds ratio higher than 1.5 over the 18 IEQ parameters. In 83 over 90 cases, we observed the odd ratios crossing 1, meaning that there is insignificant impact of that personality trait on corresponding IEQ satisfaction parameter. In other words, there is no significant difference for that IEQ satisfaction parameter when it is compared between occupants who are higher or lower in one personality trait. Further, we found some cases had an odds ratio less than 1. This implies that the occupants who are low in a personality trait has a higher likelihood, calculated by a reciprocal of the odds ratio (i.e., 1/OR), to improve the corresponding IEQ satisfaction parameter when compared to those who are high in the same trait.

We found that participants higher in Extraversion were more likely satisfied with their workspace's sound privacy (OR = 1.2, CI: 1 – 1.3) when compared to those who are more introverted. Individuals higher in Agreeableness were more satisfied with the overall workspace environment (OR = 1.4, CI: 1.1 – 1.7), cleanliness (OR = 1.2, CI: 1 – 1.5), and natural light (OR = 1.2, CI: 1 – 1.5) compared with those who are less agreeable. Those higher in Conscientiousness were more likely satisfied with the workspace's electric light (OR = 1.3, CI: 1.1 – 1.7)) and cleanliness (OR = 1.2, CI: 1 – 1.5), but less likely satisfied with overall privacy (OR = 0.8, CI: 0.7 – 1) and sound privacy (OR = 0.8, CI: 0.7 – 1), compared to those lower in Conscientiousness. Interestingly, we found no significant difference for any IEQ parameters when examining levels of Emotional Stability. Lastly, participants higher in Openness tended to be more satisfied with level of personal control (OR = 1.2, CI: 1 – 1.4) in workspace when compared with those who were in the less open to experience group.

Similarly, we found that both sex (OR: 1 – 1.2) and age (OR: 0.9 – 1.2) had little influence on the 18 IEQ satisfaction parameters. Despite the low odds ratio ranges found for sex, our findings show that male respondents were more likely satisfied with the workspace's natural light (OR = 1.3, CI: 1.1 – 1.6), humidity (OR = 1.3, CI: 1 – 1.6), and glare (OR = 1.3, CI: 1 –

1.6) than female respondents. Meanwhile, older participants were more likely satisfied with workspaces' temperature (OR = 1.1, CI: 1 – 1.3) and stuffiness (OR = 1.1, CI: 1 – 1.3), but less likely satisfied with workspaces' glare (OR = 0.9 (1/OR = 1.1), CI: 0.8 – 1) when compared with their younger counterparts.

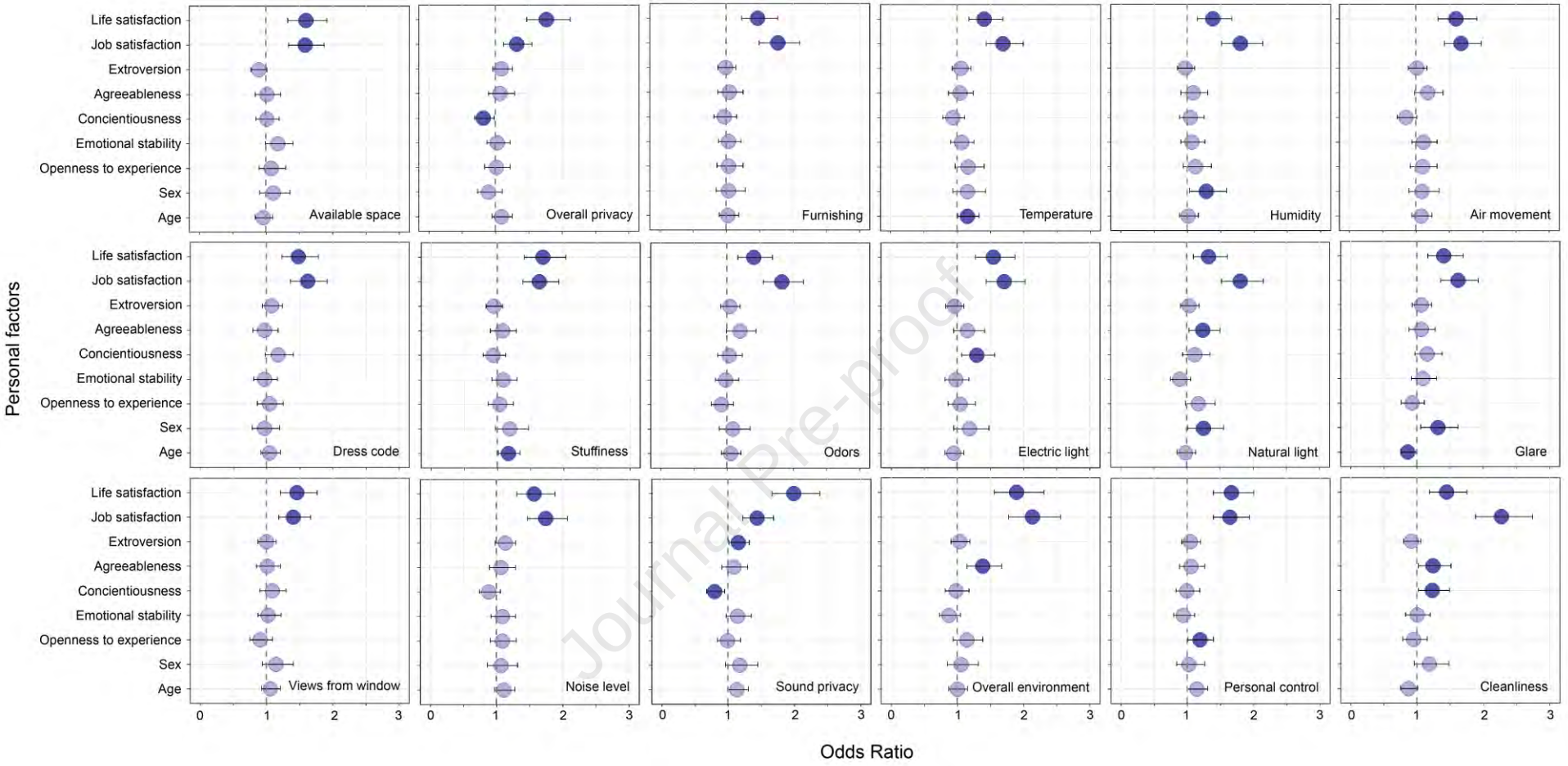

Figure 5 Proportional odds ordinal logistic regression on the 18 IEQ satisfaction parameters based on 9 personal factors. The reference classes (OR = 1) are: Less extravert, Less agreeable, Less conscientious, Less emotionally stable, Less open to experience, Less life satisfied, Less job satisfied, Female and Younger. The darker and lighter blue dot are, respectively, indicating the significant and insignificant (i.e., the whisker cut through OR = 1) cases. The whiskers are representing the 95% confidence interval.

4 Discussion

4.1 Job and life satisfaction

Our findings suggest that participants who are more satisfied with their job are 1.3 – 2.3 times more likely to be satisfied with their workspace environment when compared to those less satisfied; especially with regards to cleanliness and the overall environment. Substantial correlation between satisfaction with the overall environment and satisfaction with cleanliness in Singapore workspaces was also observed in a previous study [17]. As a psychological construct, job satisfaction is considered to be shaped by a combination of factors: a person's mental, physical, social and environmental conditions [57]. Additionally, the workspace environment itself can play an important role in forming and affecting job satisfaction [21,24]. For instance, office employees who do not receiving adequate appreciation for their work tend to be more dissatisfied with the indoor environmental quality of their workspace [16]. Further, the more positive an employee is about their office environment, the less likely they will be to report some sort of physical or psychological discomfort [58]. This integrated relationship between space and an employee's perception of their work may help reveal insights into why, in the current study, those higher in job satisfaction tend to be more satisfied with all IEQ parameters, especially when it comes to satisfaction with the overall environment. Given that this is an observational cross-sectional study, we cannot identify which satisfaction criteria, job or environment, is the cause or effect of this relationship. However, we can speculate that job and satisfaction with workspace environment and its features may be mutually supportive. Future work should aim to understand the direction and intensity of the causal relationship and potential covariant.

We also found that participants' life satisfaction was highly correlated with their job satisfaction (ρ = 0.5, p-value $\leq$ 0.01); thus suggesting these two factors may influence one another as well. Nevertheless, even when excluding the possible confounding effect of job satisfaction, our results still suggest that those higher in life satisfaction are more likely (1.3 – 2 times) to also report higher levels of satisfaction with all the IEQ parameters when compared with those less satisfied with life. In general, we observed higher (or at least comparable) OR between job – environmental satisfaction when compared to life – environmental satisfaction; interestingly, exceptions were found in satisfaction with overall privacy and sound privacy. We anticipated that privacy is a factor that penetrating through a deeper personal level compared to other IEQ parameters in Figure 5. Among couples of important domains in life, satisfaction with privacy was found having a significantly positive effect on life satisfaction on Chilean workers [59]. Meanwhile, a study in Nigeria suggested that privacy was a good moderator in the relationship between dwelling unit and life satisfaction [60]. Hypothetically, scaling down this finding to a workspace, privacy could also be a moderator between workstation environment and occupant life satisfaction.

It is worth noting life satisfaction is an amalgamation of satisfaction within a number of life domains including work, relationships, family, personal development and health. To be high on overall life satisfaction, one would likely be higher in each of, or the majority of, these domains. But it's important to consider that in this work we are measuring life satisfaction as a whole, and have only further assessed one of these domains (job satisfaction) in isolation. Examined together, these findings suggest that perhaps those more satisfied with life, or with their job, may have stronger tolerance for, and thus may tend to be more satisfied, with their workspace. In the interpretation of our results, we are utilizing a top-down approach [61], meaning we are inferring that increased satisfaction with one's life (or their job) would result in higher tolerance and satisfaction with their workspace environment. But the reverse could also be true; those more tolerant with environments in general (inside or outside of the workplace) may result in higher satisfaction with life or job [22,29,35].

4.2 Big Five personality traits

Our findings suggested that those higher in Extraversion were more satisfied with sound privacy when compared with those less extraverted. Compared to introverts, extraverts tend to be individuals who are more sociable talkative, and sensation or activity seeking within their environments [49]. These characteristics may help explain this greater degree for tolerance and satisfaction when it comes to sound privacy within space. Similar findings in another study also reported that less extroverted individuals were more sensitive to surrounding noise, as well to sound privacy [62].

We found that those higher in Agreeableness were more likely to be satisfied with the overall workspace environment, cleanliness and natural light when compared to their less agreeable counterparts, which it is aligned with a previous study [41]. Those lower in this trait tend to be less cooperative, more focused on their own needs, and less likely to sympathize or perspective take with others. Conversely, individuals high in Agreeableness tend to be cooperative and altruistic (among other things). This regard for others, at times even above and beyond one's regard for one's self, could help explain this difference for tolerance in the space overall.

In our sample, people with higher Conscientious scores proved to be more satisfied with electric light and cleanliness, but less satisfied with overall privacy and sound privacy. Conscientious individuals tend to be highly self-disciplined, dutiful, orderly, and organized [49]. It is reasonable to expect that a person high in this trait may be more likely to keep their own surroundings organized and tidy to some degree, perhaps tidying their own desk and immediate surroundings more regularly. On the other hand, those lower in Conscientiousness may be more laid back and less aware of how their surroundings are organized and maintained, thus caring less about cleanliness and the appearance of the environment overall. In addition, those lower in this trait may be less deliberate and less likely to appraise challenges, or more likely to have a stronger tolerance or flexibility in how they respond to environmental characteristics that could influence privacy (like sound privacy and overall privacy; see Figure 5). Similar findings also reported that lower conscientious individuals give less attention to their concern for privacy compared to those higher in Conscientiousness [63].

It is interesting to note that this study yielded no significant differences on IEQ satisfaction and a person's level of Emotional Stability. This is counter to what we might expect based on our knowledge of this trait. People lower in Emotional Stability tend to be more anxious, and also attuned to their surroundings (theoretically in an effort to anticipate or mitigate sources of anxiety). Further, in adjacent work looking at how the Big Five manifest within physical space, we tend to see Emotional Stability present through the types of and arrangement of items within one's surrounding [36,39,55,64]. Therefore if Emotional Stability is linked to the types of things one puts into their space, it is surprising to see it does not appear to influence one's impressions of their surroundings. Currently, we are unable to provide a solid answer for this finding, but it worth further investigation for similar study in the future.

Lastly, we observed that people who are more Open to Experience were also more likely satisfied with their level of personal control in the workspace. People high in this trait tend to be more comfortable with abstract (vs. black and white) thinking and tend to be more accepting of cultures, behaviour, and lifestyles that differ from their own [49,65]. Shared space by definition requires individuals to be with, and possibly influenced by, others. Perhaps those higher in Openness (i.e., more likely to not only accept, but even thrive, with parameters outside their immediate control, like other individuals) are more able to adapt and need less personal control over these types of spaces.

Overall, these links between traits and perceptions of space are reasonable when considering the Five Factor model of personality. It is believed that these traits interplay with our personal motives and needs to inform and dictate the way we think, feel, and behave in our daily lives [66]. Winter et al.

theorize that personality traits act as a channel through which our motivations can be expressed in our daily environments [66]. If spaces help support people's daily motives and needs, by furthering our understanding of the links between personality traits and physical space, we unlock deeper understanding of not only how people relate to their environments, but potentially, how we can create environments that are most supportive to the individual's using them.

4.3 Sex and age

Despite the small odds ratios in general, our analyses revealed that males are more satisfied than females in satisfaction with humidity, natural light, and glare. Similar findings are also reported in another study using a predominantly North American POE database, which indicated that females were more likely to be dissatisfied with the majority of the IEQ parameters analysed compared to males, except with regards to overall environmental satisfaction. [67]. There could be a number of reasons for findings like these. There is some evidence supporting this difference in sensitivity with regards to thermal conditions [14], stuffy air [68], lighting and privacy [69], and other environmental irritations [70]. Differences like these could indicate a more refined ability for women to detect IEQ variance compared to men. But before drawing strong conclusions about sex differences, we should also consider the evolution and history of the workforce, and thus the design of the common office space. It is only in the past 2-3 decades that women have begun to equal men in the workforce [71]. Because of this gender gap, it's reasonable to make the hypothesis that workspaces in general, and the policies for these spaces, may not have been designed with women, or gender equality, in mind. In addition to workplace and workforce culture, geographic cultural also likely plays a role in differences between sexes at work. We caution against drawing any clear individual differences in psychological perceptions between the sexes without more substantial cultural investigation, historical framing, and proper design of experiments that allow for the control of confounders and causative analysis.

Although some studies show that younger occupants, compared to those that are older, are more likely to be dissatisfied with the thermal environment, odors, and noise [14,68], our analyses did not reveal significant differences with regards to age for most of the indoor environmental parameters. We observed that older respondents were more satisfied with workspace temperature and stuffiness, but dissatisfied with workspace glare compared to younger individuals. Most surveys conducted in this study were in open plan offices, but we also surveyed senior level employees (usually older in age) who occupied enclosed offices with personal control over the air conditioning system. These factors could explain why elder occupants were more satisfied with workspace temperature and stuffiness. Physiology and the typical aging processes are most likely the reason behind higher dissatisfaction with glare for older occupants. Ageing eyes may change the shape of one's lenses which can cause scattered incident light rather than focused light on the retina, thus resulting more glare. In addition, research shows older occupants with ageing eyes require 3 times longer to recover from glare exposure compared to their younger counterparts [72]. Cataracts, which are common for older individuals, could also contribute to issues with glare [73]. In contrast, some other recent studies reported opposite findings, showing that younger populations are more sensitive and likely to complain about glare compared to older individuals [74,75]. Occupants' age in the current study does not appear to affect satisfaction with IEQ in a consistent and substantial way; which is consistent with another large scale POE project [12].

4.4 Impacts to overall workspace environment

We examined the impact of occupants' satisfaction with the overall workspace environment with both those personal factors that were significant (i.e., job satisfaction, life satisfaction and Agreeableness in Figure 5) and satisfaction with the 17 IEQ parameters. Detailed analyses on the

impact of the 17 IEQ satisfaction parameters to overall environment satisfaction in workspace have been analysed and discussed in a previous study [17].

The results, shown in Figure 6, suggest that overall workspace satisfaction has a positive impact on individual's satisfaction with cleanliness (OR = 2.1, CI: 1.7 – 2.6), noise level (OR = 1.5, CI: 1.3 – 1.8), electric light (OR = 1.4, CI: 1.1 – 1.7), flexibility in dress code (OR = 1.4, CI: 1.2 – 1.6), furnishings (OR = 1.3, CI: 1.2 – 1.5), personal control (OR = 1.3, CI: 1.1 – 1.5), sound privacy (OR = 1.2, CI: 1.1 – 1.4), air movement (OR = 1.2, CI: 1 – 1.5), natural light (OR = 1.2, CI: 1 – 1.4), and views from a window (OR = 1.2, CI: 1 – 1.4). Compared with Figure 5, the impacts on satisfaction with overall environment and job satisfaction (OR = 1.2, CI: 1 – 1.5), life satisfaction (OR = 1, CI: 0.8 – 1.2) and Agreeableness (OR = 1.2, CI: 1 – 1.3) were substantially lower. We anticipated this change is due to a stronger correlation observed between the overall environment satisfaction and the satisfaction with other IEQ parameters (ρ = 0.41 – 0.67) (values presented in a previous study [17]) than the correlation with job satisfaction (ρ = 0.54), life satisfaction (ρ = 0.36) and Agreeableness (ρ = 0.15) (see Figure 5). Regardless of the drop in the odds ratio, job satisfaction in Figure 6 remains an impactful variable in determining occupant's satisfaction with the overall workspace environment. . Therefore, we recommend including job satisfaction as a core question in future POE assessments because of its significance to the satisfaction with overall workspace environment. Inclusion of this variable could allow for better prediction of overall environmental satisfaction in the workplace.

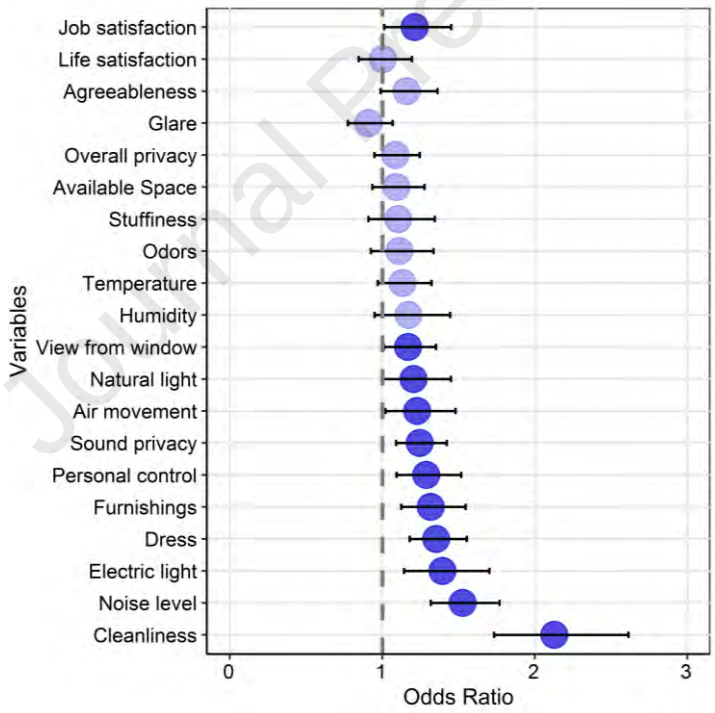

Figure 6 Proportional odds ordinal logistic regressions for the overall workspace environment satisfaction based on personal factors and participants' satisfaction with 17 IEQ parameters. The reference classes (OR = 1) were represented by the less satisfied group. Representations of the dot colour and whiskers are the same as in Figure 5.

5 Limitations

There are some limitations in this study. First, this is an observational study. The major limitation of an observational study is its inability to show the cause-and-effect association between dependent (IEQ satisfaction) and independent variables (personal factors). We assumed the directional relationship (i.e., personal factors affect subject IEQ satisfaction responses) based on limited evidence in the literature and this may lead to biased effect estimations. Secondly, due to under-exploration in this field, in particular the links between occupants' IEQ satisfaction and their life

satisfaction and personality, it is possible that there are some undiscovered confounders in our conceptual model (Figure 1). Nevertheless, our findings confirmed correlational relationships between psychological factors and occupant satisfaction. These results could be useful evidence for future causal research with better experimental control. Lastly, we assumed the 7-point satisfaction scale as numeric inputs, i.e., very satisfied (+3), neither satisfied nor dissatisfied (0), and very dissatisfied (-3), in our analysis. This scaling may not typical in all disciplines, but similar numeric transformations are commonly applied in multiple previous studies in the literature.

6 Conclusion

We conducted a post-occupancy evaluation (POE) assessment in 9 commercial buildings in Singapore (1162 respondents), to evaluate the impact of their satisfaction with life, satisfaction with job and personality traits on occupant's indoor environmental quality (IEQ) satisfaction. These analyses have rarely been explored in the field. Occupants were most satisfied with electric light ($S_{\%}$ = 85 %), cleanliness (84 %), and flexibility of dress code (80 %), while mostly dissatisfied with sound privacy ($D_{\%}$ = 42 %), personal control (25 %), and overall privacy (25 %). We found 50 % and 75 % of the participants were satisfied with their life and current job respectively. Participants in our database were higher in Agreeableness (mean [s.d.] = 5.06 [0.94]), Conscientiousness (5.26 [1]), Emotional Stability (5.01 [1.06]), and Openness to Experiences (4.71 [0.91]), while the sample reflected a more normal distribution with regards to Extraversion (3.99 [1.20]).

By applying an ordinal odds logistic regression, we found occupants' job satisfaction has the largest impact, while life satisfaction has the second highest impact, on satisfaction with the overall environment. We suspected increased satisfaction with one's job and life would results in higher satisfaction and tolerance with the workspace environment. However, a reverse explanation could also be valid, where the actual cause and effect of this relationship cannot be identified in this study. In general, the Big Five personality traits have low correlations with most of the IEQ satisfaction parameters. Nevertheless, our findings showed that those higher in Extraversion were more satisfied with sound privacy; those higher in Agreeableness were more likely to be satisfied with the overall workspace environment, cleanliness and natural light; those higher in Conscientious were more satisfied with workspace's electric light and cleanliness, but less satisfied with overall privacy and sound privacy; and those higher in Openness to Experience were more satisfied with the level of personal control in the workspace. Interestingly, we did not observe any significant impact on IEQ satisfaction and a person's level of Emotional Stability. Due to a substantially higher impact of job satisfaction on overall workspace environment satisfaction, compared with other IEQ satisfaction parameters, we recommend including job satisfaction as a core question in future POE assessments.

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Appendices

In this study, we used the satisfaction with life scale (Figure A.1) and the Ten-Item Personality Inventory (Figure A.2), respectively, to quantify subject's life satisfaction and their Big 5 Personality Traits. The questions being asked and the scoring system are presented as follow.

Questions: Below are five statements that you may agree or disagree with. Using the 1 - 7 scale below, indicate your agreement with each item by placing the appropriate number on the line preceding that item. Please be open and honest in your responding.

Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1	2	3	4	5	6	7

1. ____ In most ways my life is close to my ideal.
2. ____ The conditions of my life are excellent.
3. ____ I am satisfied with my life
4. ____ So far I have gotten the important things I want in life
5. ____ If I could live my life over, I would change almost nothing

Scoring: Though scoring should be kept continuous (sum up scores on each item), here are some cut-offs to be a benchmark. The score that used in our study is normalized (i.e. divided by 5).

Extremely dissatisfied	Dissatisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Satisfied	Extremely satisfied
5 – 9	10 – 14	15 – 19	20	21 – 25	26 – 30	31 – 35

Figure A.1. Satisfaction with life scale

Questions: Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1	2	3	4	5	6	7

I see myself as:

1. ____ Extraverted, enthusiastic
2. ____ Critical, quarrelsome.
3. ____ Dependable, self-disciplined
4. ____ Anxious, easily upset
5. ____ Open to new experience, complex
6. ____ Reserved, quiet
7. ____ Sympathetic, warm
8. ____ Disorganized, careless
9. ____ Calm, emotionally stable
10. ____ Conventional, uncreative

TIPI scale scoring ("R" denotes reverse-scored items) by adding the score of two questions:

Extraversion	Agreeableness	Conscientiousness	Emotional Stability	Openness to Experience
1, 6R	2R, 7	3, 8R	4R, 9	5, 10R

Figure A.2. Ten-Item Personality Inventory – (TIPI)

Highlights

- We conducted post-occupancy surveys in 9 buildings (1162 respondents) in Singapore
- Occupants high in job satisfaction are 1.3 – 2.3 times more satisfied with IEQ
- Occupants high in life satisfaction are 1.3 – 2 times more satisfied with IEQ
- Weak relationships between the Big Five personality traits and IEQ satisfaction
- Recommend including occupants job satisfaction questions in future POE assessments

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: