sustainability

MDPI

Article

Human Factors in Green Office Building Design: The Impact of Workplace Green Features on Health Perceptions in High-Rise High-Density Asian Cities

Fei Xue [1], Zhonghua Gou [2,*] and Stephen Siu Yu Lau [1]

[1] School of Design and Environment, National University of Singapore, 21 Lower Kent Ridge Rd., Singapore 117566, Singapore; sdexf@nus.edu.sg (F.X.); stephenlau@nus.edu.sg (S.S.Y.L.)

[2] Cities Research Centre, School of Environment, Griffith University, Parklands Drive, Southport, Gold Coast, QLD 4215, Australia

* Correspondence: z.gou@griffith.edu.au or gouzhonghua@gmail.com; Tel.: +61-7-5552-9510

Academic Editor: Chi-Ming Lai

Received: 15 September 2016; Accepted: 21 October 2016; Published: 26 October 2016

Abstract: There is a growing concern about human factors in green building, which is imperative in high-rise high-density urban environments. This paper describes our attempts to explore the influence of workplace green features (such as green certification, ventilation mode, and building morphology) on health perceptions (personal sensation, sensorial assumptions, healing performance) based on a survey in Hong Kong and Singapore. The results validated the relationship between green features and health perceptions in the workplace environment. Remarkably, participants from the air-conditioned offices revealed significant higher concerns about health issues than those participants from the mixed-ventilated offices. The mixed-ventilation design performs as a bridge to connect the indoor environment and outdoor space, which enables people to have contact with nature. Additionally, the preferred building morphology of the workplace is the pattern of a building complex instead of a single building. The complex form integrates the configuration of courtyards, podium gardens, green terrace, public plaza, and other types of open spaces with the building clusters, which contributes to better health perceptions. This research contributes to the rationalization and optimization of passive climate-adaptive design strategies for green buildings in high-density tropical or subtropical cities.

Keywords: green building; workplace; human factors; health and well-being; high-density cities

1. Introduction

There is a growing concern about human factors in green building development [1]. Occupant behavior is a driving factor of energy use in office buildings, which depends on the comfort criteria of personal choice [2]. Overtime is a common phenomenon in contemporary societies that triggers serious encumbrance of energy saving [3], as well as occupants' well-being [4]. The fact that employees are the biggest expense in an office operation has compelled organizations to improve health, well-being, and productivity via optimization of workplace environments: daylighting, natural ventilation, natural view, open space, places of respite, and other comforts [5–8]. These healthy office design strategies have been addressed in a number of leading green building rating systems [9] such as U.S. LEED, China Green Building Evaluation standard, Hong Kong BEAM Plus, and Singapore Green Mark (Table 1). These green features are well articulated: the mission to maximize health, well-being, and productivity outcomes is compatible with or even enhanced by strategies to minimize energy and resource uses.

Table 1. Green features related to health and well-being in major green building rating systems.

Green Features	Rating Systems	Criteria
Natural Ventilation	LEED V4 Building Design and Construction	Demonstrate that the system design for occupied spaces employs appropriate strategies in Chartered Institution of Building Services Engineers (CIBSE) Applications Manual AM10, March 2005, Natural Ventilation in Non-Domestic Buildings, Section 2.4.
	BEAM Plus New Building V1.2	The occupied premises designed to utilize natural ventilation request to provide a minimal background ventilation to control indoor air pollutants
	Green Mark New Building V4.1	Encourage the building design to facilitate good natural ventilation with a minimum average wind velocity of 0.6 m/s within the functional space/units.
Daylight and View Quality	LEED V4 Building Design and Construction	To connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting by introducing daylight into space.
		To give building occupants a connection to the outdoor environment by providing quality views with a direct line of sight to the outdoors via vision glazing for 75% of all regularly occupied floor area. View glazing in the contributing area must provide a clear image of the exterior.
	BEAM Plus New Building V1.2	Encourage a holistic examination of site layout, building design, and fenestration design, such as to maximize access to daylight for improved health and comfort.
	Green Mark New Building V4.1	Encourage design that optimizes the use of effective daylighting to reduce energy use for artificial lighting.
Green Space	LEED V4 Building Design and Construction	Provide outdoor space greater than or equal to 30% of the total site area (including building footprint). A minimum of 25% of that outdoor space must be vegetated (turf grass does not count) or have overhead vegetated canopy.
	BEAM Plus New Building V1.2	Using pervious materials for a minimum of 50% of hard landscaped areas; providing appropriate planting on site equivalent to at least 30%/40% of the site area.
	Green Mark New Building V4.1	Provision of greenery within the developments including rooftop/sky garden and a green roof. Green Plot Ratio is calculated by considering the 3D volume covered by plants (Leaf Area Index).
Programmes and Amenities	LEED V4 Building Design and Construction	To promote walkability, transportation efficiency and reduce vehicle distance traveled; to improve public health by encouraging daily physical activity.
	BEAM Plus New Building V1.2	Providing at least three amenity features that enhance the quality and functionality of a building to the benefit of building users, i.e., recreational facilities, balconies, common areas, etc.

Previous studies have drawn attention to the interrelations between the workplace environment and occupants' health and well-being outcomes. Based on the theories of environmental psychology, the immediate environment and green features of open space adjacent to the workplace contribute to the occupants' use behaviors and health perceptions [10–12]. However, the intermediating causal links between the objective built environment and subjective health perception in the workplace are less discussed. This research aims to investigate the following two questions: (a) What are the differences of health perceptions among occupants in the workplace with diverse green features? (b) What are the correlations between occupants' health perceptions and the green features in the workplace environment? An empirical study has been conducted in high-rise high-density Asian cities (Hong Kong and Singapore) to explore the two questions. The high pressure of rapid urbanization and overpopulation concentration in southeast Asian cities has facilitated a high-density compact urban form, which triggers serious concerns over human health and life quality. The significance of health promotion in the workplace has become increasingly valued by private and public organizations, who recognize the essentiality of a healthy, qualified, and motivated workforce in future globalizing competitions [13]. This research contributes to promote the health perceptions of office occupants in

high-density tropical or subtropical cities by rationalizing and optimizing passive climate-adaptive design strategies in office buildings design.

2. Materials and Methods

2.1. Literature Review

It is notable that green certification may affect the perceived health evaluation of building occupants [14–16]. The green-certified buildings employed a set of strategies that could improve occupants' satisfaction both physically and psychologically [17–19]. Among green building strategies, natural ventilation is usually prioritized as an effective strategy for reducing energy cost and enhancing indoor environmental quality [20]. Seppänen et al. evaluated the quantitative relationship between work performance and ventilation rate and concluded that fresh air could reduce tiredness and promote the efficiency of decision-making [21]. Another large-scale questionnaire survey disclosed that occupants in the mechanical ventilation-based open-plan offices were more likely to perceive thermal discomfort, poor air quality, noise, and negative symptoms than those occupants in natural ventilation offices [22]. In addition to fresh air and indoor environmental quality, windows can bring sunlight and views of nature, generating greater work satisfaction [23] and release work-related stress [24]. Lottrup et al. found that the employees' physical and visual access to workplace greenery was associated with a positive workplace attitude and decreased level of stress [25]. Leather et al. also identified that windows in a workplace brought a view of trees, flowers, and other natural elements, which mitigated the negative impact of job stress on staff turnover rate and promoted effects on general well-being [24].

The previous studies interpreted the benefits of building and nature integration and the interrelations between indoor and outdoor domains; however, some indecisive issues of the current workplace studies required further exploration. For example, building morphology, such as individual building or building cluster, and property program (i.e., commercial setting or institutional setting) seldom came into considered in the investigations. Building morphology is associated with the facility program and spatial arrangement. The pattern of building morphology is intimately associated with the configuration of green space [26]. Based on the combination of high-rise towers and podiums, it is available to create courtyards, podium/sky gardens, green roof, among others, for health promotion and energy conservation [27,28]. Specifically, high quality, mixed-use building complexes with available amenities and services are highly beneficial to office occupants [1] and conducive to work stress reduction [4]. Additionally, the building layout and spatial arrangement can regulate the onsite environmental performance [29,30]. On the other hand, the perceived work stress and environmental evaluations can be discrepant among different professional groups and property programs, which are located among the commercial offices and academic institutions [31]. Particularly, Bowen et al. identified that the stress level in a commercial workplace, (i.e., construction consultant) was significantly and inversely associated with the work environment among the criteria of job demand, job control, and support variables [32]. Another study found that architectural and environmental design features and strategies in institutional environments could alleviate stress and promote restoration [33].

Based on the aforementioned literature review, the green features of the workplace selected were green certification, ventilation mode, visual connection to outdoors, building morphology, and property program. The research hypotheses are proposed as follows: (1) health perceptions are differing between certified green buildings and non-green buildings; (2) health perceptions are differing between air-conditioned and mixed-ventilated buildings; (3) health perceptions are differing between offices with and without visual connections to outdoor green space; (4) health perceptions are differing between single buildings and building clusters; and (5) health perceptions are differing between commercial and institutional settings.

2.2. Data Collection

Fourteen cases were investigated in the cross-sectional questionnaire survey, which are located in the high-rise high-density urban context and adjacent to a green space or an open area. The details of building information are summarized in Table 2. The names of buildings were not disclosed in this article due to research ethics and consent forms signed by the building owners and participants. A total of 413 eligible occupants completed the survey. The criteria of selection of participants were limited to those occupants who worked daily for eight hours or above and had been in the same workplace for more than six months. The demographic profiles of the participants are summarized in Table 3. It is noted that 203 participants came from Hong Kong while 210 of which came from Singapore. The number of male (47.7%) and female (52.3%) responses are approximately equal. The majority of participants (58.1%) are between 26 and 40 years old, and the majority (63.0%) had postgraduate education level. Most (79.9%) people reported a healthy status, 18.4% were neutral, and 1.9% reported an unhealthy status. The dichotomies of workplace green features are presented in Table 4. Specifically, 51.1% of the respondents (n = 211) came from commercial settings (i.e., regular office towers) while the rest were from institutional settings (i.e., research centers or educational campuses); 59.3% of the respondents (n = 245) occupied certified green offices, while the rest were in non-green offices; 53.3% of the respondents (n = 220) worked in mixed-ventilation (combining both air-conditioning and natural ventilation) offices, while the remainder worked in air-conditioned offices; 47.2% of the respondents (n = 195) declared visual connection to outdoor green space from their workstation, while the remainder worked without visual connection to outdoor green space; 54.0% of the occupants' offices (n = 223) were located in building clusters with complex morphologies, while the rest were in single buildings with simple morphologies.

Table 2. General building information of selected cases in Hong Kong and Singapore.

List	Region	Property Program	Year of Built or Retrofit	Building Certificate	Building Morphology	Ventilation Mode
1	Hong Kong	Commercial Setting	2003	LEED O+M GOLD; Beam Plus EB Platinum	Building cluster	Air conditioning
2	Hong Kong	Commercial Setting	2008	Beam Plus NB Platinum	Building cluster	Air conditioning
3	Hong Kong	Commercial Setting	1990s	NIL	Building cluster	Air conditioning
4	Hong Kong	Commercial Setting	1990s	NIL	Individual building	Air conditioning
5	Hong Kong	Institutional Setting	1990s	NIL	Individual building	Air conditioning
6	Hong Kong	Institutional Setting	2012	LEED BD+C Platinum; Beam Plus NB Platinum	Building cluster	Air conditioning
7	Hong Kong	Institutional Setting	2012	BEAM Plus NB Provisional Gold	Individual building	Mixed ventilation
8	Singapore	Commercial Setting	2000s	NIL	Individual building	Mixed ventilation
9	Singapore	Commercial Setting	2000s	NIL	Building cluster	Air conditioning
10	Singapore	Commercial Setting	2010	Green Mark Platinum	Building cluster	Mixed ventilation
11	Singapore	Commercial Setting	2013	Green Mark Platinum	Building cluster	Mixed ventilation
12	Singapore	Institutional Setting	1990s	NIL	Building cluster	Mixed ventilation
13	Singapore	Institutional Setting	2012	Green Mark Platinum	Individual building	Mixed ventilation
14	Singapore	Institutional Setting	2011	Green Mark Platinum	Individual building	Mixed ventilation

Table 3. Demographic information of the participants from Hong Kong and Singapore (*n*= 413).

Demographic Information	Number	Percentage
Region		
Hong Kong	203	49.2%
Singapore	210	50.8%
Gender		
male	197	47.7%
female	216	52.3%
Age		
25 and below	86	20.8%
26–40	240	58.1%
41–60	80	19.4%
61 and above	7	1.7%
Education level		
Secondary school	23	5.6%
College/academy	130	31.5%
Postgraduate	260	63.0%
Self-reported health status		
Healthy	329	79.7%
Neutral	76	18.4%
Unhealthy	8	1.9%

Table 4. Green features and participants from Hong Kong and Singapore (*n* = 413).

Green Features	Number	Percentage
Certification		
Green building	245	59.3%
Non-green building	168	40.7%
Ventilation mode		
Air-conditioning	193	46.7%
Mixed-ventilation	220	53.3%
Visual connection		
Connection with outdoor green space	195	47.2%
No connection with outdoor green space	218	52.8%
Building morphology		
Building cluster	223	54.0%
Individual building	190	46.0%
Property programme		
Commercial setting	211	51.1%
Institutional setting	202	48.9%

2.3. Structure of Measurement

A self-administrated questionnaire was employed to test the divergence of health perceptions regarding diverse green features. In this research, the reference of "heal" refers to the alleviation of stress and the ability of the environment to soothe and restore one's mental and emotional health, rather than the idea of curing a person [34]. This research measures health perceptions using three categories: personal sensation, sensorial assumptions, and healing performance (Table 5). Twelve variables were configured in this survey to place the occupants' health perceptions into the three categories. Firstly, personal sensation represents the physical and psychological well-being relevant to the status of overall health [35]. Secondly, sensorial assumption indicates the appreciation of human perception in the built environment of everyday life [36]. It queries the perceived healing perceptions of sensorial stimulations, including the visual connection with nature [24], landscape aesthetics design [37], auditory design [38],

olfactory design [36], haptic design [39], gustatory design [40], and thermal comfort design [29]. Thirdly, healing performance reflects the quality of spatial merits and requirements from occupants [41]. The function of meditation and relaxation in the healing environment were included to define the therapeutic environment [42]. Therefore, healing space could be integrated into the daily workplace, which helps distract occupants from negative sentiments and pressures, and fosters mind restoration and emotional well-being. The survey used a 5-point Likert scale, where 1 was "no concern" and 5 was "strong concern". "Concern" means something that aroused their attentions and should be improved. So, the higher concern, the more negative the perception.

Table 5. Questionnaire structure for health perceptions.

Domain	Category	Questions	Measurement
Health Evaluation	Personal Sensation	Physical feeling (PF)	1 No concern to 5 Strong concern
		Psychological perception (PP)	1 No concern to 5 Strong concern
	Sensorial Assumptions	Visual connection (VC)	1 No concern to 5 Strong concern
		Aesthetics (LA)	1 No concern to 5 Strong concern
		Auditory perception (AP)	1 No concern to 5 Strong concern
		Olfactory perception (OP)	1 No concern to 5 Strong concern
		Haptic perception (HP)	1 No concern to 5 Strong concern
		Gustatory perception (GP)	1 No concern to 5 Strong concern
		Thermal comfort (TC)	1 No concern to 5 Strong concern
	Healing Performance	Meditation and relaxation (MR)	1 No concern to 5 Strong concern
		Healing efficacy (HE)	1 No concern to 5 Strong concern
		Healing requirement (HR)	1 No concern to 5 Strong concern

Cronbach's alpha for the twelve variables is 0.888, which indicates a high consistency between these variables. According to the correlation analysis, all the indicators are strongly and positively correlated with each other (Table 6). Therefore, the three indices are summarized based on grouped standard scores (Z-scores) after standardizing from the individual variables of each item [18]. The Z-scores reveal the divergence between an individual score and the mean value (i.e., a positive score represents the data above the group mean while a negative score refers to the data below the group mean) [43]. The formula of Z-score is presented in Equation (1) [44], where X stands for an individual score of each participant, μ is the mean value of each variable, and σ refers to the standard deviation of each item.

Table 6. Correlations between overall health perception (n = 413).

	PF	PP	VC	LA	AP	OP	HP	GP	TC	MR	HE	HR
PF	1	0.782 **	0.477 **	0.444 **	0.384 **	0.317 **	0.336 **	0.311 **	0.110 *	0.408 **	0.447 **	0.392 **
PP		1	0.463 **	0.440 **	0.385 **	0.314 **	0.310 **	0.292 **	0.099 *	0.384 **	0.428 **	0.362 **
VC			1	0.718 **	0.586 **	0.441 **	0.426 **	0.389 **	0.172 **	0.519 **	0.500 **	0.422 **
LA				1	0.572 **	0.469 **	0.498 **	0.413 **	0.206 **	0.491 **	0.527 **	0.469 **
AP					1	0.557 **	0.480 **	0.445 **	0.196 **	0.412 **	0.451 **	0.416 **
OP						1	0.503 **	0.532 **	0.216 **	0.352 **	0.464 **	0.400 **
HP							1	0.544 **	0.316 **	0.335 **	0.461 **	0.452 **
GP								1	0.240 **	0.350 **	0.418 **	0.371 **
TC									1	0.249 **	0.226 **	0.219 **
MR										1	0.633 **	0.486 **
HE											1	0.615 **
HR												1

* Significant at the 0.05 level (2-tailed); ** Significant at the 0.01 level (2-tailed). PF—physical feeling; PP—psychological perception; VC—visual connection; LA—landscape aesthetics; AP—auditory perception; OP—olfactory perception; HP—haptic perception; GP—gustatory perception; TC—thermal comfort; MR—meditation and relaxation; HE—healing efficacy; HR—healing requirement.

$$Z = \frac{X - \mu}{\sigma}, \quad (1)$$

Therefore, the sensation index is calculated in Equation (2):

$$\text{Sensation index} = (Z\text{-}_{PF} + Z\text{-}_{PP})/2, \quad (2)$$

Hence, the assumption index is calculated in Equation (3):

$$\text{Assumption index} = (Z\text{-}_{VC} + Z\text{-}_{LA} + Z\text{-}_{AA} + Z\text{-}_{OA} + Z\text{-}_{HA} + Z\text{-}_{GA} + Z\text{-}_{TC})/7, \quad (3)$$

Accordingly, the performance index is calculated in Equation (4):

$$\text{Performance index} = (Z\text{-}_{MR} + Z\text{-}_{HE} + Z\text{-}_{HR})/3, \quad (4)$$

3. Delimitations and Limitations

Different from previous research focusing on indoor environmental qualities and related building services controls of workplaces, this research addresses the impact of general work environments (both indoors and outdoors) on health perceptions, especially sensorial experience. Limitations of this work are related to the method and a number of relevant issues: (1) the analysis did not consider the potential impact of the age of the building and the psychological effect on people of being a new or new-looking building; (2) although health status as an item was included in the questionnaire, the analysis did not consider other subjective factors (e.g., moods, backgrounds, and family relations) that might influence their perceptions; and (3) the survey established a general link between green features and health perceptions, however, this link needs more in-depth investigation to identify in what way the subjects were concerned with their environment.

4. Results

Independent *t*-test was employed to identify whether differences of health perception were significant between the diverse categories of green features. The *t*-test is a statistical approach to compare means between unrelated groups on the same continuous variable [43]. The *p* value was set at the 0.05 level to indicate statistical significance. The quantitative data was processed and analyzed using IBM SPSS Statistics Version 23.0.

4.1. Comparison of Green Features

4.1.1. Green Certificate

Table 7 compares mean scores and standard deviations between respondents from the certified green buildings and non-green buildings. It is observed that the non-green group reported higher scores on most of the items than the green group. The results indicated that there is no statistical difference of the three indices between the green group and non-green group. In a detailed analysis, the results have confirmed that occupants from the non-green buildings revealed higher concerns on thermal comfort ($p = 0.019$) and meditative therapy ($p = 0.047$) in their workplaces. However, there is no significant difference in personal sensation, healing perception, and other sensorial assumptions between the green group and non-green group. In sum, the divergences between participants from the green buildings and non-green buildings are focused on the (1) concern of thermal comfort in sensorial assumptions and (2) meditation therapy in healing performance.

Table 7. Comparison between the green group (n = 245) and the non-green group (n = 168).

Category	Indicator	Group	Mean	Std. Deviation	*t*-Test for Equality of Means			
					t	Df	Sig. (2-Tailed)	Mean Diff.
Integrated Index	Sensation index	Green	−0.043	0.935	−1.124	411.000	0.262	−0.106
		Non-Green	0.063	0.957	−1.119	353.492	0.264	−0.106
	Assumption index	Green	−0.048	0.719	−1.665	411	0.097	−0.119
		Non-Green	0.070	0.697	−1.675	366.161	0.095	−0.119
	Performance index	Green	−0.062	0.832	−1.808	411	0.071	−0.153
		Non-Green	0.091	0.865	−1.795	349.787	0.074	−0.153
Personal Sensation	Physical feeling	Green	4.18	0.587	−0.366	411	0.715	−0.023
		Non-Green	4.20	0.671	−0.357	326.838	0.722	−0.023
	Psychological perception	Green	4.22	0.606	−1.759	411	0.079	−0.105
		Non-Green	4.32	0.582	−1.772	368.052	0.077	−0.105
Sensorial Assumption	Visual connection	Green	4.42	0.543	−1.792	411	0.074	−0.099
		Non-Green	4.52	0.568	−1.777	348.070	0.076	−0.099
	Landscape aesthetics	Green	4.37	0.562	−1.957	411	0.051	−0.111
		Non-Green	4.48	0.568	−1.953	356.568	0.052	−0.111
	Auditory stimulation	Green	4.25	0.684	−1.367	411	0.172	−0.092
		Non-Green	4.35	0.657	−1.378	368.580	0.169	−0.092
	Olfactory stimulation	Green	4.04	0.737	0.351	411	0.726	0.027
		Non-Green	4.02	0.815	0.344	334.709	0.731	0.027
	Haptic stimulation	Green	3.98	0.768	−0.057	411	0.955	−0.004
		Non-Green	3.99	0.797	−0.056	350.330	0.955	−0.004
	Gustatory stimulation	Green	3.99	0.741	−1.137	411	0.256	−0.086
		Non-Green	4.08	0.766	−1.130	351.131	0.259	−0.086
	Thermal comfort	Green	4.06	0.750	−2.350	411	0.019 *	−0.175
		Non-Green	4.23	0.734	−2.359	364.010	0.019	−0.175
Healing Performance	Meditation and relaxation	Green	4.27	0.634	−1.994	411	0.047 *	−0.129
		Non-Green	4.40	0.667	−1.976	347.099	0.049	−0.129
	Healing efficacy	Green	4.21	0.637	−0.944	411	0.346	−0.062
		Non-Green	4.27	0.672	−0.934	346.191	0.351	−0.062
	Healing requirement	Green	4.04	0.748	−1.657	411	0.098	−0.124
		Non-Green	4.16	0.745	−1.658	360.120	0.098	−0.124

* Significant at the 0.05 level (2-tailed); ** Significant at the 0.01 level (2-tailed).

4.1.2. Ventilation Mode

Table 8 shows the divergences between the two kinds of ventilation mode, viz. air-conditioning (AC) and mixed-ventilation (MV). Overall, participants from the AC group reported higher concerns than the MV group on personal sensation, healing performance, and, most of all, sensorial assumptions. Based on the *t*-test, it is observed that the sensation index fails Levene's Test of the null hypothesis of equal variances. The performance index is significantly higher in the AC group than in the MV group (p = 0.003). However, there is no statistical difference of the assumption index between the two groups. Further analyses revealed that the AC group reported higher concerns with visual connection with nature (p = 0.006), aesthetics (p = 0.011), and auditory stimulation (p = 0.020). However, participants from the MV buildings were concerned with thermal comfort more significantly than those from the AC group (p < 0.000). Also, the AC group reported greater concerns with meditative therapy (p = 0.036), healing efficacy (p = 0.009), and requirement of healing space (p = 0.003) in the workplace than those from the MV group. In sum, the influence power of ventilation mode could significantly impact human perception mostly on the variables of personal sensation, sensorial assumption, and healing performance of the environmental settings.

Table 8. Comparison between mixed-ventilation group (n = 220) and air-conditioning group (n = 193).

Category	Indicator	Group	Mean	Std. Deviation	*t*-Test for Equality of Means			
					t	Df	Sig. (2-Tailed)	Mean Diff.
Integrated Index	Sensation index	Mixed mode	−0.117	0.918	−2.718	411.000	0.007 #	−0.251
		Air-con	0.134	0.958	−2.711	399.013	0.007	−0.251
	Assumption index	Mixed mode	−0.035	0.702	−1.072	411	0.284	−0.075
		Air-con	0.040	0.723	−1.070	400.792	0.285	−0.075
	Performance index	Mixed mode	−0.117	0.835	−3.029	411	0.003 **	−0.251
		Air-con	0.134	0.844	−3.027	402.919	0.003	−0.251
Personal Sensation	Physical feeling	Mixed mode	4.11	0.610	−2.807	411	0.005 #	−0.171
		Air-con	4.28	0.625	−2.802	401.298	0.005	−0.171
	Psychological perception	Mixed mode	4.20	0.584	−2.321	411	0.021 #	−0.136
		Air-con	4.33	0.607	−2.315	399.368	0.021	−0.136
Sensorial Assumptions	Visual connection	Mixed mode	4.40	0.551	−2.738	411	0.006 **	−0.149
		Air-con	4.54	0.549	−2.738	404.478	0.006	−0.149
	Landscape aesthetics	Mixed mode	4.35	0.574	−2.561	411	0.011 *	−0.142
		Air-con	4.49	0.551	−2.568	407.644	0.011	−0.142
	Auditory stimulation	Mixed mode	4.22	0.674	−2.343	411	0.020 *	−0.155
		Air-con	4.37	0.666	−2.345	405.253	0.020	−0.155
	Olfactory stimulation	Mixed mode	4.06	0.722	0.711	411	0.478	0.054
		Air-con	4.01	0.820	0.705	385.731	0.481	0.054
	Haptic stimulation	Mixed mode	3.92	0.764	−1.752	411	0.080	−0.134
		Air-con	4.06	0.792	−1.748	399.787	0.081	−0.134
	Gustatory stimulation	Mixed mode	4.02	0.721	−0.244	411	0.808	−0.018
		Air-con	4.04	0.786	−0.242	392.521	0.809	−0.018
	Thermal comfort	Mixed mode	4.25	0.693	3.582	411	0.000 ***	0.260
		Air-con	3.99	0.784	3.554	386.388	0.000	0.260
Healing Performance	Meditation and relaxation	Mixed mode	4.26	0.656	−2.109	411	0.036 *	−0.135
		Air-con	4.39	0.638	−2.113	406.678	0.035	−0.135
	Healing efficacy	Mixed mode	4.16	0.646	−2.624	411	0.009 **	−0.167
		Air-con	4.33	0.647	−2.623	403.849	0.009	−0.167
	Healing requirement	Mixed mode	3.99	0.749	−2.949	411	0.003 **	−0.216
		Air-con	4.20	0.733	−2.953	406.159	0.003	−0.216

* Significant at the 0.05 level (2-tailed); ** Significant at the 0.01 level (2-tailed); *** Significant at the 0.001 level (2-tailed); # Failure of Levene's Test for equality of variances.

4.1.3. Building Morphology

Table 9 presents the potential divergences of health perception between the two building morphologies (i.e., cluster building and individual building). It is verified that compared with the individual group, participants from the cluster group reported slightly higher concerns for personal sensation and healing performance, but slightly lower concerns for the sensorial assumption. According to the *t*-test, there are no statistical differences between the three integrated indices. The detailed analyses testified that participants from the individual group revealed higher concerns for thermal comfort than the occupants from the cluster group ($p < 0.000$). However, there is no significant difference in other health-oriented variables. In sum, the morphology of buildings could significantly impact the perceived thermal comfort in the workplace, but with limited influence on the occupant perception of other environmental sensorial stimulations.

Table 9. Comparison between the cluster group (n = 223) and the individual group (n = 190).

Category	Indicator	Group	Mean	Std. Deviation	*t*-Test for Equality of Means			
					t	Df	Sig. (2-Tailed)	Mean Diff.
Integrated Index	Sensation index	Cluster	0.0150	0.943	0.349	411	0.727	0.033
		Individual	−0.0176	0.947	0.349	400.066	0.727	0.033
	Assumption index	Cluster	−0.045	0.726	−1.388	411	0.166	−0.097
		Individual	0.053	0.693	−1.393	405.653	0.164	−0.097
	Performance index	Cluster	0.004	0.861	0.097	411	0.922	0.008
		Individual	−0.004	0.834	0.098	404.312	0.922	0.008
Personal Sensation	Physical feeling	Cluster	4.20	0.607	0.457	411	0.648	0.028
		Individual	4.17	0.639	0.456	393.396	0.649	0.028
	Psychological perception	Cluster	4.26	0.598	0.202	411	0.840	0.012
		Individual	4.25	0.599	0.202	400.387	0.840	0.012
Sensorial Assumption	Visual connection	Cluster	4.49	0.552	1.127	411	0.260	0.062
		Individual	4.43	0.557	1.126	399.618	0.261	0.062
	Landscape aesthetics	Cluster	4.42	0.546	0.022	411	0.982	0.001
		Individual	4.42	0.592	0.022	388.655	0.982	0.001
	Auditory stimulation	Cluster	4.29	0.683	−0.116	411	0.908	−0.008
		Individual	4.29	0.665	−0.116	403.837	0.907	−0.008
	Olfactory stimulation	Cluster	3.98	0.777	−1.487	411	0.138	−0.113
		Individual	4.09	0.757	−1.490	403.645	0.137	−0.113
	Haptic stimulation	Cluster	3.95	0.809	−1.111	411	0.267	−0.085
		Individual	4.03	0.741	−1.119	408.835	0.264	−0.085
	Gustatory stimulation	Cluster	3.96	0.788	−1.836	411	0.067	−0.136
		Individual	4.10	0.702	−1.853	410.160	0.065	−0.136
	Thermal comfort	Cluster	4.01	0.805	−3.565	411	0.000 ***	−0.259
		Individual	4.27	0.648	−3.627	409.685	0.000	−0.259
Healing Performance	Meditation and relaxation	Cluster	4.34	0.629	0.483	411	0.629	0.031
		Individual	4.31	0.676	0.481	390.024	0.631	0.031
	Healing efficacy	Cluster	4.22	0.653	−0.442	411	0.659	−0.028
		Individual	4.25	0.650	−0.442	401.286	0.659	−0.028
	Healing requirement	Cluster	4.09	0.762	0.206	411	0.837	0.015
		Individual	4.08	0.734	0.206	404.895	0.837	0.015

* Significant at the 0.05 level (2-tailed); ** Significant at the 0.01 level (2-tailed); *** Significant at the 0.001 level (2-tailed).

Based on the data analysis, it is observed that there is no significant difference in health perceptions between the criteria of property program and visual connection. This finding suggested that for the commercial company and research institution, the perceived health evaluation of the occupants might be analogous to each other as far as the computer-based workplace is concerned. On the other hand, due to the various layout plans and orientations, the status of natural view from one's workstation might be discrepant within the same workplace. Moreover, some respondents work in an unfixed position whose workstation could be changed from time to time. Therefore, the visual connection to outdoors from the workstation might not be determinate for the environmental assessment in this research.

4.2. Healing Perception vs Green Features

The evaluations of thermal comfort are significantly different regarding the building certification, ventilation mode, and morphology (Figure 1). It is remarkable that the occupants of non-green buildings revealed higher concern for thermal comfort of microclimate conditions than those from the green buildings. The result indicates that the quality of thermal comfort might be better in green buildings than non-green buildings. Second, the respondents from mixed ventilated buildings were more concerned about the thermal comfort than those from the AC buildings in both cities. Since natural ventilation is available in the mixed ventilation office, occupants behaved more sensitively towards thermal comfort than those who work in the AC office. Third, the occupants from single

buildings showed a higher concern for thermal comfort than those from complex buildings in both cities. The spatial arrangement in building clusters was usually associated with a series of shaded open space (i.e., courtyard, podium garden, etc.), which significantly promotes a shading effect and reduces excessive solar heat gains in workplace environments.

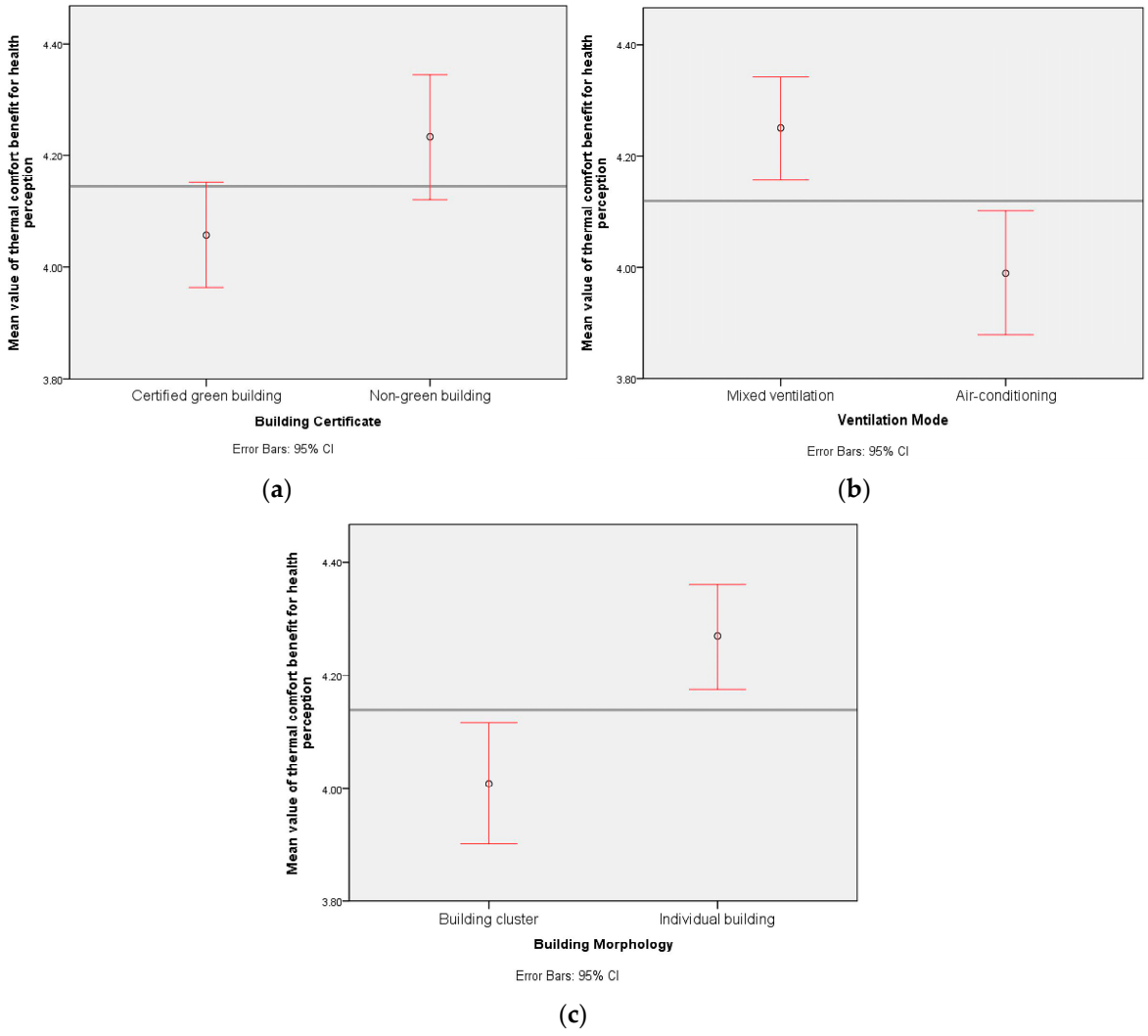

Figure 1. (**a**) Comparison of thermal comfort evaluation between building certification status; (**b**) comparison of thermal comfort evaluation between ventilation modes; (**c**) comparison of thermal comfort evaluation between building morphologies.

As shown in Figure 2, it is verified that the concern for meditation and relaxation could be influenced by building certification and ventilation mode, respectively. Occupants from non-green buildings showed a greater need for meditative function in workplaces than those from the green buildings. Likewise, the participants from AC group showed their needs were greater for natural therapy than those from the MV group.

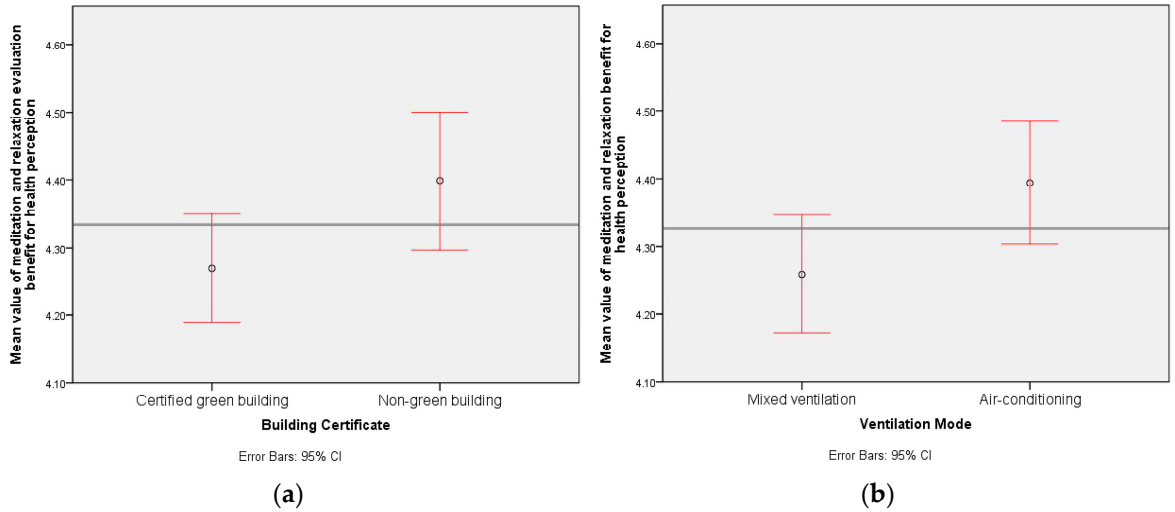

Figure 2. (**a**) Comparison of meditation and relaxation between building certification status; (**b**) comparison of meditation and relaxation between ventilation modes.

As shown in Figure 3, it is notable that the evaluation between AC group and MV group on healing efficacy and healing requirements in the workplace environment is significantly different. The occupants from AC buildings revealed remarkably higher concern for healing efficacy than those from MV buildings. The score gap between the AC group and MV group is even larger from the perspective of healing requirement. The results demonstrate that participants from AC buildings are longing for the natural restoration and fresh air in the high-rise and high-density Asian context.

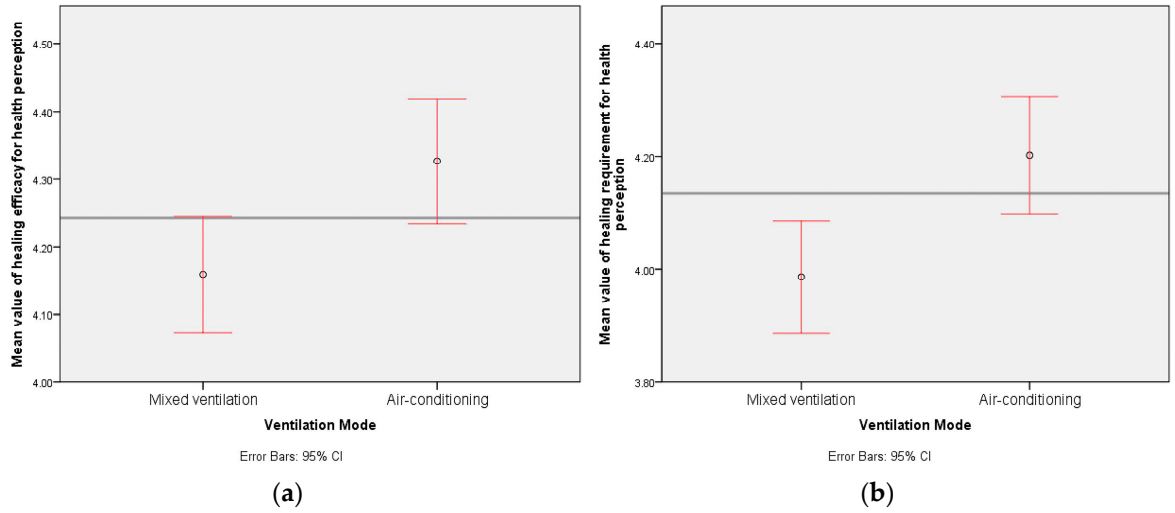

Figure 3. (**a**) Comparison of healing efficacy between different ventilation modes; (**b**) comparison of healing requirement between different ventilation modes.

5. Discussion

This paper presents a comparative analysis of health perceptions between diverse building green features. The overall outcomes of the individual comparisons are summarized in Table 10. The results identified that the ventilation mode between mixed-ventilation and air-conditioning dominated the overall health perception, while the criteria of building certification and building morphology partially influenced the sensorial perception in the workplace.

Table 10. Overall outcomes of the comparative analysis.

Comparative Category		Personal Sensation		Sensorial Assumption						Healing Performance			
		PF	PP	VC	LA	AS	OS	HS	GS	TC	MR	HE	HR
Green Features	Building certification	–	–	–	–	–	–	–	–	√	√	–	–
	Ventilation mode	√	√	√	√	√	–	–	–	√	√	√	√
	Building morphology	–	–	–	–	–	–	–	–	√	–	–	–
	Building function	–	–	–	–	–	–	–	–	–	–	–	–
	Visual connection	–	–	–	–	–	–	–	–	–	–	–	–

Note: √: Health evaluation impacted by the selected variables; –: Health evaluation doesn't impact by the selected variables; PF—physical feeling; PP—psychological perception; VC—visual connection; LA—landscape aesthetics; AS—auditory stimulation; OS—olfactory stimulation; HS—haptic stimulation; GS—gustatory stimulation; TC—thermal comfort; MR–meditation and relaxation; HE—healing efficacy; HR—healing requirement.

The divergence of personal sensation and sensorial assumption reflect the different perceptions between natural ventilation and air-conditioning. Previous studies verified that natural ventilation promoted significant merits for human health and performance in the diverse layout of workplace settings compared with the mode of air-conditioning [21]. The inferior ventilation affected by a poor air-conditioning system and the absence of natural ventilation could lead to heterogeneous air temperature and humidity in the indoor environment, as well as inadequate oxygen provision from personal perceptions [6,45]. Further, the operable window in the mixed-ventilation system enabled the occupants to regulate the ventilation rate of fresh air and control the exchange of thermal comfort with the outdoor space [1,6]. Primarily, the evaluation of healing performance could be influenced by the innate attachment between human and nature. Besides the indoor air quality enhancement [14] and energy conservation promotion [20], the mixed ventilation (MV) design performs as a bridge to connect the indoor environment and outdoor green space. The perception of naturally ventilated space enables people to connect with nature through the sound of birds and the wind, as well as the change of weather and time [46], which is consistent with the Biophilia hypothesis that there is an instinctive affinity between human beings and other living systems [47,48].

Furthermore, the influences of other green features (i.e., green certification, building morphology, property program, and visual connection) are limited. Although this research verified the superior quality of green buildings that stipulate the workplace environmental quality [14,49,50], further details of site configurations and features are requested to be present. The healing performance of built environments (between the complex building and the single building) should be further examined. The findings further suggested that the professionals of the program settings did not significantly influence the perceived health evaluations, based on the feedbacks of the occupants. It could be inferred that the psychological pressures on the computer-based workplaces are analogous among the diverse professionals who are well-educated, possess specialized knowledge, and cope with the social responsibility [51]. On the other hand, due to the various layout plans and orientations, the status of visual connection to outdoors from one's workstation might be discrepant in the same workplace. Some respondents work in an unfixed position whose workstation could be changed from time to time. Therefore, the visual connection to outdoors from the workstation might not be determinate for the health perception in this research.

6. Conclusions

This paper presents a comparative study of health perception in the workplace towards between diverse green features in the high-density subtropical and tropical Asian context. The study validates that the associations of the green features in the corresponding urbanscape could significantly impact perceived health evaluations in workplace settings. Remarkably, the criteria of ventilation mode could significantly affect the occupant's concern of personal sensation, sensorial assumption, and healing performance. The mixed-mode ventilation system is recommended for the workplace, rather than the air-conditioning ventilation system. Most importantly, the perception of natural ventilation has

endowed people the circadian rhythm from outdoor space through the sound of birds and the wind, and the changes of weather and time. Further, the enhanced landscape and greenery regulations in the green buildings could significantly alleviate the negative perception of microclimate conditions in the environmental perception, more so than the non-green buildings. Additionally, the preferred building morphology of the workplace is the pattern of a building complex instead of a single building. Besides the mixed services and facilities, the complex form integrates the configuration of courtyards, podium gardens, green terrace, public plaza, and other such spaces with the building clusters, which contribute to better spatial perceptions.

Under the great challenges of limited land resource, overpopulation concentration, and restricted climate conditions in the high-density Asian context, the authors suggest that the strategies mentioned above are of great importance to the clients, professionals, and managers in workplace design, construction, and management.

Acknowledgments: The authors express gratitude to the University of Hong Kong and National University of Singapore for scholarships and fellowships to enable raw data collection in the two cities. Many thanks are also due to the three anonymous reviewers who provided instructive comments and guidance to revise this paper.

Author Contributions: All of the authors equally contributed to the work in this paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. World Green Building Council (WGBC). Health, Wellbeing & Productivity in Offices: The Next Chapter for Green Building. In *Health, Wellbeing and Productivity*; World Green Building Council, Ed.; World Green Building Council: London, UK, 2014.
2. Hong, T.; Lin, H.-W. Occupant Behavior: Impact on Energy Use of Private Offices. In Presented at the ASim 2012—1st Asia Conference of International Building Performance Simulation Association, Shanghai, China, 25–27 November 2012.
3. Sun, K.; Yan, D.; Hong, T.; Guo, S. Stochastic Modeling of Overtime Occupancy and Its Application in Building Energy Simulation and Calibration. *Build. Environ.* **2014**, *79*, 1–12. [CrossRef]
4. Michie, S. Causes and Management of Stress at Work. *Occup. Environ. Med.* **2002**, *59*, 67–72. [CrossRef] [PubMed]
5. Hraska, J. Chronobiological Aspects of Green Buildings Daylighting. *Renew. Energy* **2015**, *73*, 109–114. [CrossRef]
6. Gou, Z.; Lau, S.Y. Sick Building Syndrome in Open-Plan Offices: Workplace Design Elements and Perceived Indoor Environmental Quality. *J. Facil. Manag.* **2012**, *10*, 256–265. [CrossRef]
7. Shahzad, S.S.; Brennan, J.; Theodossopoulos, D.; Hughes, B.; Calautit, J.K. Building-Related Symptoms, Energy, and Thermal Control in the Workplace: Personal and Open Plan Offices. *Sustainability* **2016**, *8*, 331–350. [CrossRef]
8. Byrd, H.; Rasheed, E.O. The Productivity Paradox in Green Buildings. *Sustainability* **2016**, *8*, 347–358. [CrossRef]
9. Lam, K.; Zhang, R.; Wang, H.; Dong, B.; Zhang, R. Development of Web-Based Information Technology Infrastructures and Regulatory Repositories for Green Building Codes in China (Icodes). *Build. Simul.* **2013**, *6*, 195–205. [CrossRef]
10. Lee, A.C.; Maheswaran, R. The Health Benefits of Urban Green Spaces: A Review of the Evidence. *J. Public Health* **2011**, *33*, 212–222. [CrossRef] [PubMed]
11. Kaplan, S.; Kaplan, R. Health, Supportive Environments, and the Reasonable Person Model. *Am. J. Public Health* **2003**, *93*, 1484–1489. [CrossRef] [PubMed]
12. Chang, C.-Y.; Chen, P.-K. Human Response to Window Views and Indoor Plants in the Workplace. *HortScience* **2005**, *40*, 1354–1359.
13. World Health Organization (WHO). Workplace Health Promotion. Available online: http://www.who.int/occupational_health/topics/workplace/en/ (accessed on 10 August 2016).
14. U.S. Green Building Council (USGBC). *Leed V4 Reference Guide for Building Design and Construction*; Green Building Council: Washington, DC, USA, 2013.

15. BRE. *Breeam International New Construction Technical Manual 2013*; BRE Group Training: London, UK, 2013.
16. U.S. Green Building Council (USGBC). *Leed 2009 for Healthcare*; Green Building Council: Washington, DC, USA, 2012.
17. Gou, Z.; Prasad, D.; Lau, S.-Y. Impacts of Green Certifications, Ventilation and Office Types on Occupant Satisfaction with Indoor Environmental Quality. *Archit. Sci. Rev.* **2014**, *57*, 196–206. [CrossRef]
18. Gou, Z.; Prasad, D.; Lau, S.-Y. Are Green Buildings More Satisfactory and Comfortable? *Habitat Int.* **2013**, *39*, 156–161. [CrossRef]
19. Gou, Z.; Lau, S.-Y. Contextualizing Green Building Rating Systems: Case Study of Hong Kong. *Habitat Int.* **2014**, *44*, 282–289. [CrossRef]
20. Kubba, S. *Handbook of Green Building Design and Construction: Leed, Breeam, and Green Globes*; Butterworth-Heinemann: Waltham, MA, USA, 2012.
21. Seppänen, O.; Fisk, W.J.; Lei, Q.H. Ventilation and Performance in Office Work. *Indoor Air* **2006**, *16*, 28–36. [CrossRef] [PubMed]
22. Pejtersen, J.; Allermann, L.; Kristensen, T.S.; Poulsen, O.M. Indoor Climate, Psychosocial Work Environment and Symptoms in Open-Plan Offices. *Indoor Air* **2006**, *16*, 392–401. [CrossRef] [PubMed]
23. Boubekri, M.; Hull, R.B.; Boyer, L.L. Impact of Window Size and Sunlight Penetration on Office Workers' Mood and Satisfaction: A Novel Way of Assessing Sunlight. *Environ. Behav.* **1991**, *23*, 474–493. [CrossRef]
24. Leather, P.; Pyrgas, M.; Di, B.; Lawrence, C. Windows in the Workplace: Sunlight, View, and Occupational Stress. *Environ. Behav.* **1998**, *30*, 739–762. [CrossRef]
25. Lottrup, L.; Grahn, P.; Stigsdotter, U.K. Workplace Greenery and Perceived Level of Stress: Benefits of Access to a Green Outdoor Environment at the Workplace. *Landsc. Urban Plan.* **2013**, *110*, 5–11. [CrossRef]
26. Yeang, K. *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings*; Prestel: Munich, Germany; London, UK; New York, NY, USA, 1999.
27. Yeang, K. *Eco Skyscrapers*, 1st ed.; Images Publishing: Mulgrave, Australia, 2011; Volume 2.
28. Yeang, K.; Spector, A. (Eds.) *Green Design: From Theory to Practice*; Black Dog: London, UK, 2011.
29. Givoni, B. *Climate Considerations in Building and Urban Design*; Van Nostrand Reinhold: New York, NY, USA, 1998.
30. Oke, T.R. Canyon Geometry and the Nocturnal Urban Heat Island: Comparison of Scale Model and Field Observations. *J. Climatol.* **1981**, *1*, 237–254. [CrossRef]
31. Chan, K.B.; Lai, G.; Ko, Y.C.; Boey, K.W. Work Stress among Six Professional Groups: The Singapore Experience. *Soc. Sci. Med.* **2000**, *50*, 1415–1432. [CrossRef]
32. Bowen, P.; Edwards, P.; Lingard, H.; Cattell, K. Occupational Stress and Job Demand, Control and Support Factors among Construction Project Consultants. *Int. J. Proj. Manag.* **2014**, *32*, 1273–1284. [CrossRef]
33. Lau, S.-Y.; Gou, Z.; Liu, Y. Healthy Campus by Open Space Design: Approaches and Guidelines. *Front. Archit. Res.* **2014**, *3*, 452–467. [CrossRef]
34. Vapaa, A.G. Healing Gardens: Creating Places for Restoration, Meditation, and Sanctuary. Master's Thesis, Virginia Polytechnic Institute and State University, Blacksburg, WV, USA, 2002.
35. Grad, F.P. Preamble to the Constitution of the World Health Organization. *Bull World Health Organ.* **2002**, *80*, 981–982. [PubMed]
36. Malnar, J.M.; Vodvarka, F. *Sensory Design*; Minneapolis University of Minnesota Press: Minneapolis, MN, USA, 2004.
37. Tveit, M.; Ode, Å.; Fry, G. Key Concepts in a Framework for Analysing Visual Landscape Character. *Landsc. Res.* **2006**, *31*, 229–255. [CrossRef]
38. Hunter, M.D.; Eickhoff, S.B.; Pheasant, R.J.; Douglas, M.J.; Watts, G.R.; Farrow, T.F.D.; Hyland, D.; Kang, J.; Wilkinson, I.D.; Horoshenkov, K.V.; et al. The State of Tranquility: Subjective Perception Is Shaped by Contextual Modulation of Auditory Connectivity. *NeuroImage* **2010**, *53*, 611–618. [CrossRef] [PubMed]
39. Gibson, J.J. *The Senses Considered as Perceptual Systems*; Houghton Mifflin: Boston, MA, USA, 1966.
40. Brewer, J.M.; Shavit, A.Y.; Shepard, T.G.; Veldhuizen, M.G.; Parikh, R.; Marks, L.E. Identification of Gustatory—Olfactory Flavor Mixtures: Effects of Linguistic Labeling. *Chem. Senses* **2013**, *38*, 305–313. [CrossRef] [PubMed]
41. Sternberg, E.M. *Healing Spaces: The Science of Place and Well-Being*; Belknap Press of Harvard University Press: Cambridge, MA, USA, 2009.
42. Lea, J. Retreating to Nature: Rethinking 'Therapeutic Landscapes'. *Area* **2008**, *40*, 90–98. [CrossRef]

43. Field, A. *Discovering Statistics Using SPSS*, 3rd ed.; Sage: London, UK, 2009.
44. Aron, A.; Coups, E.J.; Aron, E.N. *Statistics for the Behavioral and Social Sciences: A Brief Course*, 5th ed.; Pearson Prentice Hall: London, UK, 2008.
45. Seppänen, O.A.; Fisk, W.J.; Mendell, M.J. Association of Ventilation Rates and CO_2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings. *Indoor Air* **1999**, *9*, 226–252.
46. Browning, W.; Ryan, C.; Clancy, J. 14 Patterns of Biophilic Design. In *Improving Health & Well-Being in the Built Environment*, 62th ed.; Terrapin Bright Green LLC: New York, NY, USA, 2014.
47. Wilson, E.O. *Biophilia*; Harvard University Press: Cambridge, MA, USA, 1984.
48. Ulrich, R.S. Biophilia, Biophobia, and Natural Landscapes. In *The Biophilia Hypothesis*; Kellert, S.R., Wilson, E.O., Eds.; Island Press: Washington, DC, USA, 1993; pp. 73–137.
49. HKGBC. *Beam Plus New Buildings Version 1.2*; BEAM Society Limited: Hong Kong, China, 2012.
50. Building and Construction Authority (BCA). *Bca Green Mark Certification Standard for New Buildings*; BCA, Ed.; Building and Construction Authority: Singapore, 2012; p. 205.
51. Eisen, K.P.; Allen, G.J.; Bollash, M.; Pescatello, L.S. Stress Management in the Workplace: A Comparison of a Computer-Based and an in-Person Stress-Management Intervention. *Comput. Hum. Behav.* **2008**, *24*, 486–496. [CrossRef]