The green office environment: New Zealand workers' perception of IEQ

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Received 22 September 2022
Revised 31 October 2022
Accepted 3 November 2022

Abstract

Purpose – Achieving an appropriate indoor environment quality (IEQ) is crucial to a green office environment. Whilst much research has been carried out across the globe on the ideal IEQ for green offices, little is known about which indoor environment New Zealand office workers prefer and regard as most appropriate. This study investigated New Zealand office workers' preference for a green environment.

Design/methodology/approach – Workers were conveniently selected for a questionnaire survey study from two major cities in the country – Wellington and Auckland. The perception of 149 workers was analysed and discussed based on the workers' demographics. The responses to each question were analysed based on the mean, standard deviation, frequency of responses and difference in opinion.

Findings – The results showed that workers' preferences for an ideal IEQ in green work environments depend largely on demographics. New Zealand office workers prefer work environments to have more fresh air and rely on mixed-mode ventilation and lighting systems. Also New Zealand office workers like to have better acoustic quality with less distraction and background noise. Regarding temperature, workers prefer workspaces to be neither cooler nor warmer. Unique to New Zealand workers, the workers prefer to have some (not complete) individual control over the IEQ in offices.

Research limitations/implications – This study was conducted in the summer season, which could have impacted the responses received. Also the sample size was limited to two major cities in the country. Further studies should be conducted in other regions and during different seasons.

Practical implications – This study provides the opportunity for more studies in this area of research and highlights significant findings worthy of critical investigations. The results of this study benefit various stakeholders, such as facilities managers and workplace designers, and support proactive response approaches to achieving building occupants' preferences for an ideal work environment.

Originality/value – This study is the first research in New Zealand to explore worker preferences of IEQ that is not limited to a particular building, expanding the body of knowledge on workers' perception of the ideal work environment in the country.

Keywords Green indoor environments, New Zealand workspaces, Workers' preferences

Paper type Research paper

1. Introduction

The recent coronavirus disease 2019 (COVID-19) pandemic has exaggerated the need for "greener" indoor environments in buildings with acceptable indoor environment quality (IEQ). The survey of 4,015 office workers worldwide (JLL Global Research, 2022) shows that

Data availability statement: All data, models and code generated or used during the study appear in the submitted article.

The authors acknowledge the contributions of research assistants (Achini Weerasinghe) and masters' students (Sahithi Pittala, Zhou Jiaye and Cong Ji) from Massey University for the data collection and background study of this project.

Smart and Sustainable Built Environment
Emerald Publishing Limited
2046-6099
DOI 10.1108/SASBE-09-2022-0204

59% of workers want to work for organisations that value their health and well-being and 38% would like to work in an office that is designed sustainably.

The survey also found that many employees work from home, as 73% of office workers go to the office at least once weekly. As a result, organisations eager to encourage their staff's return to work can no longer ignore research reporting on the widespread effects of indoor environments on building occupants' health, well-being, satisfaction, productivity and performances (Belussi *et al.*, 2019; Vilcekova *et al.*, 2017; Wong *et al.*, 2018). These factors are crucial for workers' comfort, satisfaction and productivity (Sadick *et al.*, 2020).

Studies such as Al Horr *et al.* (2016), Clausen and Wyon (2008) and Lan *et al.* (2010) have noted how poor IEQ could cause illness and adversely affect well-being and reduce worker productivity. Tarantini *et al.* (2017) and Lipczynska *et al.* (2018) observed that workers who report thermal discomfort complaints also report low productivity. Onyeizu (2014) provided an overview of studies that show a significant relationship between self-reported productivity and IEQ.

The cost implication of poor indoor environments on productivity is not left out, as value is lost when workers are unhealthy and cannot function as expected. Even before the advent of COVID-19, absenteeism, productivity losses and healthcare costs due to poor ventilation were estimated to have annual economic impacts of hundreds of billions of dollars on the USA (Frontczak *et al.*, 2012). Fisk and Rosenfeld (1997) pointed out that the risk of sick leave, illness, influenza and pneumonia are elevated at lower ventilation rates with associated productivity and health cost impacts and also highlighted is the part "presenteeism" plays (a situation where workers are present at work even though they are not productive), contributing to poor IEQ in office environments and resulting in productivity losses. For instance, workers with contagious illnesses going to work can spread the infection to colleagues and impact the productivity of the entire staff and organisation. Medibank's (2011) report shows that, on average, 6.5 working days of productivity are lost per employee annually due to presenteeism in Australia.

2. Background

Four major IEQ parameters (thermal comfort, indoor air quality (IAQ), visual comfort and acoustic comfort) dominate research on green indoor environments, accounting for the relationship between workplace design, worker comfort and productivity. Individually, the degree of influence of these parameters has often been mediated by various demographic, physical and environmental factors.

The most influential amongst the IEQ parameters is thermal comfort. Defined as a state of mind that expresses occupant satisfaction with the thermal environment (ASHRAE 55, 2020), the relationship between temperature and worker comfort, satisfaction and productivity (Woo *et al.*, 2021) is mediated by different factors (Clausen and Wyon, 2008), which are classified as environmental and human factors (Rasheed *et al.*, 2019). Environmental factors include four physical parameters: air temperature, air velocity, mean radiant temperature and relative humidity. Human factors include clothing insulation, activity level (metabolic rate), age, gender, climate, location, posture and mood (ASHRAE, 2020; Lin and Deng, 2008).

These factors mediate occupants' response to their ambient thermal environment through sensation, preference and acceptability (Elshafei *et al.*, 2017; Langevin *et al.*, 2013). As such, thermal comfort is achieved when the three primary forms of responses are in "equilibrium" with the prevailing thermal environment. This "equilibrium" occurs when an occupant is aware or conscious of the immediate environment's temperature level and approves of the temperature level as an ideal thermal condition or can accept the thermal environment as bearable if the ideal thermal condition is not met (Vischer, 2007; Langevin *et al.*, 2013).

In the absence of this "thermal equilibrium", occupants exhibit physiological responses such as acceleration, anxiety and customisation as a reaction to an unacceptable thermal condition (Abbasi *et al.*, 2019; Langevin *et al.*, 2015).

Regarding IAQ, its relationship with occupant comfort, health and productivity has recently gained more attention due to COVID-19. Much research has shown the direct and indirect links between poor IAQ and the spread of COVID-19 amongst other viruses. For example, Nwanaji-Enwerem *et al.* (2020) show that indoor spaces with poor air quality increase the rate and likelihood of COVID-19 infection. Similarly, Wu *et al.* (2020) suggest that every 10 $\mu g/m^3$ increment in UFPs (Ultra-fine particles) and nitrogen oxides could cause at least a 15–22% increase in death rates due to COVID- 19.

Factors such as ventilation rate, outdoor climatic conditions, pollution and human activities play significant roles in determining the prevalent IAQ and often fault the goal of achieving optimal indoor air-quality levels (Lan *et al.*, 2011) in a given indoor space. For example, Hosseini *et al.* (2020) pointed out that the overuse of disinfectants (e.g. chlorine-based cleaning products) causes chemical air pollution indoors. Endocrine-disrupting chemicals (EDC) such as bisphenol A, alkylphenols and perfluoroalkyl (Kiess *et al.*, 2021) are commonly found in food packages and storage containers, various electronic devices, children's toys, detergents, paints and plastic materials. They have fatal consequences, such as thyroid problems and neurodevelopment problems, and raise the predisposition to cancer (Turan, 2021; Kiess *et al.*, 2021).

Achieving IAQ where the air has zero concentration of harmful pollutants and where 80% or more of the workers are satisfied (Lan *et al.*, 2011) is complex (Al Horr *et al.*, 2016). That said, Kosonen and Tan (2004) suggested that increasing the ventilation rate enables more fresh air into the building and removes CO_2 and other air pollutants.

Accordingly, different ventilation systems, such as natural, mechanical and hybrid/mixed-mode ventilation, are available to control the ventilation rate and IAQ in buildings (Abdulaali *et al.*, 2020; Al Horr *et al.*, 2016). Over the years, there has been ongoing contention regarding which ventilation system provides more fresh air and achieves higher IAQ as benefits and limitations characterise them. For instance, some studies indicate that mixed-mode ventilation systems have higher air-quality satisfaction and energy savings than their mechanical counterparts (Amasyali and El-Gohary, 2016; Kosonen and Tan, 2004). Likewise, mechanical ventilation systems are regarded to be more effective than natural ventilation because they protect indoor spaces from outdoor pollution. However, compared to natural ventilation, mechanical ventilation systems are known to have a significantly higher association with one or more SBS (Sick Building Syndrome) symptoms (Ezzeldin and Rees, 2013) due to lower air exchange.

Visual comfort is mediated by various factors that must be considered to achieve an ideal lighting environment (Abdulaali *et al.*, 2020). Whilst some of these factors significantly correlate with visual comforts, such as psychology and physiology (Pierson *et al.*, 2017), others don't. For instance, Abboushi *et al.* (2020) found a limited to no impact of window shape and sunlight patterns on office visual work. Zhang *et al.* (2022) found no significant correlation between gender and visual comfort.

Research suggests that building occupants prefer daylight over artificial light for physiological and psychological reasons (Roskams and Haynes, 2020; Elzeyadi, 2011; Galasiu and Veitch, 2006; Leslie, 2003). If well designed, daylight can reduce health problems associated with insufficient artificial lighting levels, such as dry eyes, eye irritation, headache and allergic reaction (Abdulaali *et al.*, 2020), whilst increasing the cognitive performance of the occupants (Rea *et al.*, 2002). Artificial lighting becomes convenient if the daylight level is less adequate or unavailable (Boyce, 2010). An example is when occupants experience daylight glare inside the building due to elevated illuminance levels (Yang and Mak, 2020).

In an office environment, noise can be generated internally or externally. Internal noise is generated from conversations between co-workers, telephone ringing, printers, fax machines, kitchen equipment and mechanical systems like heating ventilation and air conditioning (HVAC) systems, compressors, generators and fans. External sources of noise in offices include sounds from vehicles, the public and other machinery (Stansfeld and Matheson, 2003; Banbury and Berry, 2005). Whereas good acoustics design on the building facades deters external noise from entering the office interior, internal noise in offices is influenced by internal arrangement and layout (Al Horr *et al.*, 2016).

As it is impossible to eliminate noise within an office environment, it is vital to mediate the effect of noise on occupants' comfort, health and productivity. For example, keeping the background noise level inside a building within an acceptable range (Hong *et al.*, 2015; Rea, 2000) is essential to the cognitive performance of workers. Building acoustics will ensure uninterrupted communication between occupants and limits noise transmission within internal spaces from room to room (Rea, 2000; Evans and Stecker, 2004).

The type of office space arrangement (private or shared spaces) mediates the relationship between acoustic comfort and work productivity. It significantly impacts the performance of acoustic design and the quality of noise in office environments. Workers in offices with open-plan layouts are more prone to privacy issues and disturbances due to various office sounds (Hygge, 2003; Balazova *et al.*, 2008). The noise from an open plan office can create fatigue, motivation and performance of employees (Toftum *et al.*, 2012), which affects tasks associated with word processing and numbers calculation. Reactive strategies such as sound masking add low-level background noise to reduce speech-to-noise ratio and intelligibility (Jahncke and Halin, 2012). Private offices with less noise and privacy issues still require good insulation and moderate background noise to mask speech when needed. Other measures, such as sound-absorbing materials on walls and ceilings inside office spaces, provide reasonable control of a room's reverberation time and good absorption ability (Kim and de Dear, 2012; Taylor, nd).

The mediating role of IEQ parameters relies on the availability of control measures in the office environment. Khoshbakht *et al.* (2021a) noted that more control over noise pollution is one sensible solution to creating productive buildings for more sensitive building users. Rasheed *et al.* (2017) emphasised the importance of occupants' control over the IEQ in office buildings. Despite the mounting evidence of the beneficial effect that providing control to occupants could have on their comfort (perceived and actual), many buildings lack adequate control measures. Societal trends have prompted more highly automated buildings that require little or no occupants' input and interaction with the building system. Most of these strategies fail to achieve predicted comfort levels as human interaction and behavioural comfort measures can skew the modelled expected outcomes. Accounting for and providing individualised occupant control over IEQ parameters in building performance predictions ensures occupant comfort amidst other targeted outcomes such as energy efficiency.

2.1 Problem statement

The importance of IEQ parameters as mediators of occupant comfort, health and productivity and the design of green work environments cannot be overstated. Therefore, building professionals such as architects, engineers and facilities managers are often expected to create green environments that provide the appropriate IEQ to increase office workers' comfort, health and productivity and reduce, if not eliminate, associated cost implications, but then creating an ideal green indoor environment requires robust research findings to support the appropriate decision-making.

Retrieving workers' preferences is an essential step in designing green work environments, as it highlights the conditions they regard as ideal. Whilst it provides the opportunity to gain necessary information before designing and constructing green office spaces, it allows for a holistic view of user-centric workplace design.

But then, most studies on IEQ and occupant comfort in work environments are post-occupancy evaluations (POE) wherein occupants are required to judge the performance of their work environments based on their experience and perception. POE results are often used to determine appropriate IEQ and influence the design of new office spaces and buildings.

The issue is that whereas POE results provide valuable indications of occupants' perception of their workspaces and needs, they are limited to specific office spaces/buildings with unique features and occupant characteristics. They do not provide generalisable information for ideal green work environments. The consequences include workplace designs that do not reflect diverse worker characteristics.

Our study expands research in this area by providing a more generalisable result that is not limited to the POE of a particular building.

Furthermore, whilst extensive studies have been undertaken globally in IEQ and office occupant comfort, research on New Zealand work environments is still in its infancy. Few authors are pioneering research on the relationship between self-evaluated comfort and indoor environment parameters in New Zealand (Weerasinghe *et al.*, 2022; Onyeizu, 2014; Rasheed *et al.*, 2019). For instance, Weerasinghe *et al.* (2022) examined the interrelation between office workers' indoor environment comfort preferences on their energy behaviours in New Zealand office buildings. Onyeizu (2014) compared workers' perceptions of IEQ in two office buildings in Auckland, New Zealand whilst exploring the impact of IEQ on worker productivity. Rasheed *et al.* (2019) found that worker performance in New Zealand office environments is highly affected by temperature extremity and control over temperature.

Our study aims to expand the body of knowledge on workers' perceptions of an ideal work environment by providing a New Zealand perspective. In this study, we delve deeper into understanding the mediating demographic factors influencing workers' perception of an ideal workspace, exploring similarities and differences in the relationship between demography and workers' preferences. It intends to support proactive response approaches to designing green work environments and promote occupant comfort as an essential consideration in workplace design.

3. Materials and methods

We conducted a perception-based study that required workers in New Zealand to evaluate their preferences for IEQ in their workplaces. We used self-evaluated comfort satisfaction questionnaires (Al Horr *et al.*, 2016; Langevin *et al.*, 2013) to achieve two objectives:

(1) To determine the prevailing preferred indoor environmental quality for New Zealand office spaces and

(2) To highlight the influence of demography and building type on workers' perception of an ideal workspace.

Office workers from two major cities were randomly selected for the study. The data collection was carried out between November 2020 and February 2021, during the summer season in New Zealand. A questionnaire was developed based on existing literature on IEQ factors, workers' comfort, satisfaction and productivity. The questions were validated through a pilot study before administering the questionnaire to office workers through Qualtrics online survey platform [1]. The questions examined in this paper are categorised to achieve the study objectives.

(1) Demographic information: age, gender, duration of residence and work and workspace type and location and

(2) IEQ preference of office workers: thermal comfort, ventilation, air quality, visual comfort, acoustic comfort and the availability of building control

A total of 149 responses were collected from workers in the country's two major cities – Auckland and Wellington. Both cities are major population centres and contain most businesses and organisations. Wellington is the capital of New Zealand and the major population centre of the southern North Island. The climate of Wellington is temperate, with warm summers and mild winters. The city is known for its windy and southerly blasts in winter, making the temperature feel much colder. Auckland is the most populated city in New Zealand and is in the central part of the North Island. Auckland has subtropical climate, with warm, humid summers and mild damp winters.

The data were collated and analysed using IBM SPSS (Statistical Package for the Social Sciences) 24. A reliability test was conducted to ensure internal consistency of the survey, and the value for Cronbach's Alpha for the survey was $\alpha = 0.67$ for ten items, showing an acceptable consistency. The demographic information about the participants is shown in Table 1. The sample comprises mostly females (61%) and younger people aged between 30 and 49 and below 30 years (71.9%). The workers have different ethnicities; however, most are Europeans (38.3%) and Asians (37.6%). Furthermore, nearly all workers have lived in New Zealand for more than 1 year (98%), with a majority having lived between 1–10 years (43%). The study participants are well familiar with their workspace and indoor environment, as most of the workers spend 8 h or more at the buildings (69.8%), have worked in the current building (76.5%) and the workspace for a year or more than a year (65.1%). Also most workers share the workspace with more than eight co-workers in cubicles or open-plan offices (38.3%).

Demography	N	Percentage				
Gender	149	61.1 (female)	36.2 (male)	2.7 (prefer not to say)		
Age	149	43.0 (30–49 years)	28.9 (below 30 years)	26.8 (50–65 years)	1.3 (above 65 years)	
Ethnicity	149	38.3 (European)	37.6 (Asian)	15.4 (Other)	6.7 (Black, Middle Eastern)	2 (Māori, Pasifika)
Time spent in NZ	149	43 (1–10 years)	40.9 (More than 20 years)	14.1 (11–20 years)	2 (Less than a year)	
Normal work base	149	90.6 (Yes)	9.4 (No)			
Time spent in the office building	149	76.5 (A year or more)	23.5 (Less than a year)			
Time spent in present workspace	149	65.1 (A year or more)	34.9 (Less than a year)			
Time spent in office building each day	149	69.8 (8 h or more)	30.2 (Less than 8 h)			
Type of office building	148	61.7 (Commercial)	27.5 (Education)	10.1 (Other)		
Time spent working at the computer each day	149	54.4 (Less than 8 h)	45.6 (8 h or more)			
Private or shared workspace	149	38.3 (Cubical or Open plan)	20.8 (Private office)	18.1 (Shared with 2–4 others)	12.8 (Shared with 1 other)	10.1 (Shared with 5–8 others)
Workspace location	149	60.4 (Close to a window within 1.5 m	20.1 (Close to an exterior wall within 1.5 m	19.5 (At the centre of the office)		

Table 1. Participants' background information

The job roles of the respondents included education, real estate, administration, design and construction. Workers' preferences were captured using open-ended questions and close-ended structured questions. The responses to the closed-ended questions were coded with rating options, whilst comments were required for the open-ended questions. Open-ended comments must accompany rating surveys to allow more insight into respondents' opinions and views on the subject matter. Open-ended questions help researchers to identify issues not covered by closed questions (Biemer *et al.*, 2004). Table 2 shows the questions relating to IEQ aspects and control over IEQ. As the study aims to investigate workers' perception of a preferred workspace, the data scales were ordinal and required simple descriptive analysis.

The results are presented based on the following categories, namely gender, age, time spent in New Zealand, type of workspace, type of building and proximity. Each parameter was analysed based on its mean, standard deviation, frequency of responses and opinion differences.

The mean shows the value that appears most frequently in a data set, whilst the standard deviation measures how dispersed the responses are. The cross-tabulation χ^2 test of goodness of test was used to determine if there are statistically significant correlation between the demographic variables and workers' preferences (Ortiz-Prado *et al.*, 2022). χ^2 has been used in past works in this area to test for correlations, associations and differences (Smajlović *et al.*, 2019; Li *et al.*, 2020).

For the respondents' comments, individual comments were analysed based on the relevance of their content to the question asked and the prevailing preferred IEQ parameters were identified using a word cloud. Word clouds represent the frequency of keywords in the respondents' comments. This provides a synopsis of the main themes contained within the comments (Atenstaedt, 2017). The results are presented in the section below.

4. Results: quantification of user perceptions and preferences

4.1 Temperature

The workers were asked to rate how they prefer the indoor temperature in their workspaces. The preference ratings received for thermal comfort are given in Table 3. The χ^2 test of goodness-of-fit showed that the preference for thermal comfort was equally distributed amongst all the demographic groups ($p > 0.05$). Generally, most respondents wanted no change to the temperature in their workspaces.

Looking at the individual demographic categories, the results were similar amongst the options except for "Time spent in New Zealand", "Workspace" and "Type of building". Those

Parameter	Questions (1–10)	Response options
Thermal Comfort	Q1: How do you prefer the indoor temperature to be in your workspace?	Cooler; No change – OK; Warmer
Air Quality	Q2: How do you prefer the air quality in your workspace?	Want more fresh air; No change – OK; Want less fresh air
Ventilation	Q3: What ventilation system do you prefer in your workspace?	Natural ventilation; Mechanical Ventilation (ceiling fans, HVAC, HRV); Mixed- Mode
Visual Comfort	Q4: What type of lighting do you prefer in your workspace?	Natural lighting; Artificial lighting; A combination of both
Acoustic Comfort	Q5: How do you prefer the noise to be in your workspace?	More noise; No change – OK; Less noise
Control	Q6 -Q10: Do you like to have control over the following indoor aspects? – heating, cooling, lighting, ventilation, noise	No control; Somewhat control; Full control; Does not matter

Table 2. Questionnaire used in the workers' preferences evaluation

No - 149	Demography	Mean	Std. Dev	Cooler (%)	No change – OK (%)	Warmer (%)	χ^2 test
Gender	Male	1.685	0.66798	42.6	46.3	11.1	$X^2 = 5.483$
	Female	1.8791	0.72778	33.0	46.2	20.9	$p = 0.241$
	Prefer not to answer	2.25	0.95743	25.0	25.0	50.0	
Age	Below 30 years	1.6512	0.65041	44.2	46.5	9.3	$X^2 = 10.610$
	30–49 years	1.9375	0.77408	32.8	40.6	26.6	$p = 0.101$
	50–65 years	1.8500	0.66216	30.0	55.0	15.0	
	Above 65 years	1.00	0.00	100.0	0.00	0.00	
Time spent in NZ	Less than a year	1.333	0.57735	66.7	33.3	0.00	$X^2 = 4.788$
	1–10 years	1.8594	0.77392	37.5	39.1	23.4	$p = 0.571$
	11–20 years	1.7143	0.64365	38.1	52.4	9.5	
	More than 30 years	1.8361	0.68752	32.8	50.8	16.4	
Workspace	Private office	1.7097	0.73908	45.2	38.7	16.1	$X^2 = 6.887$
	Shared with 1 other	2.0526	0.77986	26.3	42.1	31.6	$p = 0.549$
	Shared with 2–4 others	1.6667	0.73380	48.1	37.0	14.8	
	Shared with 5–8 others	1.8	0.67612	33.3	53.3	13.3	
	Cubicle/open plan office	1.8772	0.68322	29.8	52.6	17.5	
Proximity	1.5 m close to a window/door	1.8222	0.71230	35.6	46.7	17.8	$X^2 = 0.173$ $p = 0.996$
	1.5 m close to an exterior wall	1.8333	0.74664	36.7	43.3	20.0	
	At the centre of the office	1.7931	0.72601	37.9	44.8	17.2	
Type of building	Commercial	1.8925	0.71418	31.2	48.4	20.4	$X^2 = 4.339$
	Educational	1.7073	0.74980	46.3	36.6	17.1	$p = 0.362$
	Other	1.6667	0.61721	40	53.3	6.7	

Table 3.
Office workers' preference rating on temperature

who had spent less than a year in New Zealand were above 65 years old, stayed in a private office or shared their office paces with 2–4 other people and worked in educational buildings preferred a cooler environment than the rest who felt the temperature was OK and no change was required. The respondents' opinions varied between their preference for a cooler environment and no modification required for most of the demographics tested.

The comments from the workers supported their ratings and reflected the respective preferences of the respondents. A respondent noted their preference for a cooler temperature because it stimulates their alertness. Some workers suggested having thermal insulation in the workspace to improve the temperature inside the building and the ability to control the thermostats. Other workers reflected their preference for operable windows for increased airflow in their office spaces. Some respondents noted that because the temperature varies during the day, there is no control over it; sometimes it is too hot or too cold. A respondent maintained the ability to regulate body temperature irrespective of external temperature changes.

4.2 Air quality

The workers were asked for their preferred air-quality level and the ventilation system. From the results presented in Table 4, the χ^2 test of goodness-of-fit performed showed that the

	Demography	Mean	Std. Dev	More air (%)	No change (%)	Less air (%)	χ^2 test
Gender	Male	1.685	0.66798	42.6	46.3	11.1	$X^2 = 1.353$
	Female	1.8791	0.72778	33.0	46.2	20.9	$p = 0.852$
	Prefer not to answer	2.25	0.95743	25.0	25.0	50.0	
Age	Below 30 years	1.6512	0.65041	44.2	46.5	9.3	$X^2 = 6.913$
	30–49 years	1.9375	0.77408	32.8	40.6	26.6	$p = 0.329$
	50–65 years	1.8500	0.66216	30.0	55.0	15.0	
	Above 65 years	1.00	0.0	100.0	0	0	
Time spent in NZ	Less than a year	1.333	0.57735	66.7	33.3	0	$X^2 = 6.553$
	1–10 years	1.8594	0.77392	37.5	39.1	23.4	$p = 0.364$
	11–20 years	1.7143	0.64365	38.1	52.4	9.5	
	More than 30 years	1.8361	0.68752	32.8	50.8	16.4	
Workspace	Private office	1.7097	0.73908	45.2	38.7	16.1	$X^2 = 8.824$
	Shared with 1 other	2.0526	0.77986	26.3	42.1	31.6	$p = 0.357$
	Shared with 2–4 others	1.6667	0.73380	48.1	37.0	14.8	
	Shared with 5–8 others	1.8	0.67612	33.3	53.3	13.3	
	Cubicle/open plan office	1.8772	0.68322	29.8	52.6	17.5	
Proximity	1.5 m close to a window/door	1.8222	0.71230	35.6	46.7	17.8	$X^2 = 9.974$ $p = 0.041$
	1.5 m close to an exterior wall	1.8333	0.74664	36.7	43.3	20.0	
	At the centre of the office	1.7931	0.72601	37.9	44.8	17.2	
Type of building	Commercial	1.4839	0.52363	52.7	46.2	1.1	$X^2 = 10.425$
	Educational	1.2439	0.43477	75.6	24.4	0	$p = 0.034$
	Other	1.6667	0.48795	33.3	66.7	0	

Table 4. Preference rating on air quality

preference for IAQ was equally distributed amongst all the demographic groups ($p > 0.05$) except for proximity ($p = 0.041$) and type of building ($p = 0.034$). Most respondents wanted no change to the air quality in their workspaces. This perception was closely followed by those who desired more fresh air in their workspaces.

Based on the individual demographic category ratings, more fresh air was preferred by more respondents with age above 65 years, who spent less than a year in New Zealand, worked in private offices and shared offices with 2–4 other workers and workers in both commercial and educational buildings. Only respondents who did not identify as male or female wanted less fresh air in their workspaces. Their comments supported their views, as some workers noted a preference for a healthy and alert environment with operable windows and variable airflow.

4.3 Ventilation

Regarding the ventilation system at their workspaces, the respondents were asked to choose a mode of ventilation they prefer in their workspace – natural ventilation (with openable windows and doors), mechanical ventilation (with ceiling fans, HVAC system or heat recovery ventilation (HRV) system) or mixed-mode (a combination of natural and mechanical ventilation).

As shown in Table 5, the χ^2 test of goodness-of-fit performed showed that the preference for the type of ventilation was equally distributed amongst all the demographic groups

	Demography	Mean	Std. Dev	NV (%)	MV (%)	MM (%)	χ^2 test
Gender	Male	2.1296	0.82522	27.8	31.5	40.7	$X^2 = 10.934$
	Female	2.2088	0.92516	34.1	11.0	54.9	$p = 0.027$
	Prefer not to answer	2.5	1.0	25	0	75	
Age	Below 30 years	2.0698	0.85622	32.6	27.9	39.5	$X^2 = 6.459$
	30–49 years	2.2188	0.89918	31.3	15.6	53.1	$p = 0.374$
	50–65 years	2.225	0.91952	32.5	12.5	55	
	Above 65 years	3.0	0.0	0	0	100	
Time spent in NZ	Less than a year	2.3333	0.57735	0	66.7	33.3	$X^2 = 11.624$
	1–10 years	2.0156	0.89960	39.1	20.3	40.6	$p = 0.071$
	11–20 years	2.3810	0.80475	19	23.8	57.1	
	More than 30 years	2.2951	0.90082	29.5	11.5	59	
Workspace	Private office	1.9677	1.016	51.6	0	48.4	$X^2 = 24.283$
	Shared with 1 other	1.7368	0.87191	52.6	21.1	26.3	$p = 0.02$
	Shared with 2–4 others	2.2593	0.85901	25.9	22.2	51.9	
	Shared with 5–8 others	2.0667	0.96115	40.0	13.3	46.7	
	Cubicle/open plan office	2.4561	0.73364	14	26.3	59.6	
Proximity	1.5 m close to a window/door	2.1889	0.85977	28.9	23.3	47.8	$X^2 = 10.496$ $p = 0.033$
	1.5 m close to an exterior wall	1.9667	0.99943	50.0	3.3	46.7	
	At the centre of the office	2.4138	0.82450	20.7	17.2	62.1	
Type of building	Commercial	2.2151	0.87040	29	20.4	50.5	$X^2 = 7.282$
	Educational	2.3171	0.87861	26.8	14.6	58.5	$p = 0.122$
	Other	1.6667	0.89974	60	13.3	26.7	

Table 5. Preference rating on type of ventilation

($p > 0.05$) except for gender ($p = 0.027$), type of workspace ($p = 0.02$) and proximity ($p = 0.033$). A clear majority preferred mixed-mode ventilation. The next preferred ventilation mode was natural ventilation, justifying workers' preferences for fresh air and operable windows and doors. Mechanical ventilation was the least preferred mode of ventilation amongst the respondents.

Based on demography, the results were similar amongst the options except for respondents who had spent less than a year in New Zealand, worked in a private office or shared an office with one other person. Respondents who had spent less than a year in New Zealand preferred mechanical ventilation. Those who worked in a private or shared office with one other preferred natural ventilation. The respondents' opinions did not vary significantly between their preferences.

Regarding their comments, some workers noted that they would prefer less noise from mechanical ventilation systems and control over the ventilation systems. Also they prefer to use mechanical ventilation as a backup system when it is indispensable. It is worth noting that one respondent commented that passive ventilation does not work.

4.4 Lighting

A noteworthy rating was received for workers' preference for the type of lighting system for their workspaces. As shown in Table 6, the χ^2 test of goodness-of-fit performed showed that, unlike other IEQ parameters, the preference for lighting system was not equally distributed amongst all the demographic groups ($p < 0.05$) except for proximity ($p = 0.7$) and type of

Table 6. Preference rating on lighting system

	Demography	Mean	Std. Dev	NL (%)	AL (%)	MM (%)	χ^2 test
Gender	Male	2.5556	0.71814	13.0	18.5	68.5	$X^2 = 9.707$
	Female	2.3077	0.91521	30.8	7.7	61.5	$p = 0.046$
	Prefer not to answer	2.0	1.15470	50	0	50	
Age	Below 30 years	2.1163	0.85103	30.2	27.9	41.9	$X^2 = 22.126$
	30–49 years	2.4063	0.88585	26.6	6.3	67.2	$p = 0.001$
	50–65 years	2.6250	0.77418	17.5	2.5	80	
	Above 65 years	3.0	0.0	0	0	100	
Time spent in NZ	Less than a year	1.6667	1.1547	66.7	0	33.3	$X^2 = 13.027$
	1–10 years	2.3438	0.85855	25	15.6	59.4	$p = 0.043$
	11–20 years	2.1905	0.87287	28.6	23.8	47.6	
	More than 30 years	2.5410	0.82813	21.3	3.3	75.4	
Workspace	Private office	2.0323	1.016	48.4	0	51.6	$X^2 = 16.945$
	Shared with 1 other	2.4737	0.77233	15.8	21.1	63.2	$p = 0.031$
	Shared with 2–4 others	2.4444	0.80064	18.5	18.5	63	
	Shared with 5–8 others	2.3333	0.89974	26.7	13.3	60	
	Cubicle/open plan office	2.5439	0.78080	17.5	10.5	71.9	
Proximity	1.5 m close to a window/door	2.4333	0.83532	22.2	12.2	65.6	$X^2 = 2.195$ $p = 0.700$
	1.5 m close to an exterior wall	2.4	0.85501	23.3	13.3	63.3	
	At the centre of the office	2.2414	0.95076	34.5	6.9	58.6	
Type of building	Commercial	2.2903	0.90386	30.1	10.8	59.1	$X^2 = 8.478$
	Educational	2.6341	0.73335	14.6	7.3	78	$p = 0.076$
	Other	2.3333	0.81650	20	26.7	53.3	

building ($p = 0.076$). Generally, most workers prefer a combination of both natural and artificial lighting in their working environment.

Deductively, younger workers are below 30 years old. Generally, only respondents who did not identify as male or female and those who had spent less than a year in New Zealand preferred natural lighting over the other options. The respondents' opinions did not vary between their preferences.

Visual comfort received a considerable number of comments from respondents indicating its importance. The comments varied between both regions as workers noted the lack of control over lighting as they must cope with the preference of co-workers. Some reported their desire for natural lighting with less or no direct sunlight or glare. They do not want too bright or too dark workspaces to avoid light sensitivity; sufficient task lighting is preferred for those who work beyond daylight hours. Interestingly, some workers noted that they liked the lighting whilst they worked.

4.5 Noise

The workers acknowledged their preference for acoustic comfort. As presented in Table 7, the choice for acoustic comfort was equally distributed amongst all the demographic groups ($p > 0.05$) except for gender and type of building ($p = 0.034$ each). Generally, most respondents preferred less noise in their workspace, although their perceptions varied for all the demographics tested.

Looking at the demographics, the following groups preferred no change to the noise in their workspaces: those identified as female, were aged 30 years old and above and have

Table 7. Preference rating on noise

	Demography	Mean	Std. Dev	Less noise (%)	No change (%)	More noise (%)	χ^2 test
Gender	Male	1.4259	0.53560	59.3	38.9	1.9	$X^2 = 10.399$
	Female	1.6813	0.63033	40.7	50.5	8.8	$p = 0.034$
	Prefer not to answer	1.0	0.0	100	0	0	
Age	Below 30 years	1.3953	0.58308	65.1	30.2	4.7	$X^2 = 7.118$
	30–49 years	1.6406	0.62659	43.8	48.4	7.8	$p = 0.310$
	50–65 years	1.65	0.57957	40	55	5	
	Above 65 years	1.5	0.70711	50	50	0	
Time spent in NZ	Less than a year	1.0	0.0	100	0	0	$X^2 = 9.774$
	1–10 years	1.5156	0.64222	56.3	35.9	7.8	$p = 0.135$
	11–20 years	1.6190	0.66904	47.6	42.9	9.5	
	More than 30 years	1.6393	0.54872	39.3	57.4	3.3	
Workspace	Private office	1.7419	0.72882	41.9	41.9	16.1	$X^2 = 11.262$
	Shared with 1 other	1.5263	0.61178	52.6	42.1	5.3	$p = 0.187$
	Shared with 2–4 others	1.5926	0.50071	40.7	59.3	0	
	Shared with 5–8 others	1.5333	0.51640	46.7	53.3	0	
	Cubicle/open plan office	1.4912	0.60127	56.1	38.6	5.3	
Proximity	1.5 m close to a window/door	1.5889	0.65161	50	41.1	8.9	$X^2 = 4.809$ $p = 0.307$
	1.5 m close to an exterior wall	1.4667	0.50742	53.3	46.7	0	
	At the centre of the office	1.6207	0.56149	41.4	55.2	3.4	
Type of building	Commercial	1.6022	0.66168	49.5	40.9	9.7	$X^2 = 10.415$
	Educational	1.4390	0.50243	56.1	43.9	0	$p = 0.034$
	Other	1.7333	0.45774	26.7	73.3	0	

spent more than 30 years in New Zealand. Interestingly, those who shared their workspaces with 2–8 other people and were located at the centre of their office space were also okay with the noise levels and preferred no change to the acoustics quality in their offices.

Acoustic preference received the highest number of comments for all the IEQ factors investigated. Workers noted that they could hear people in nearby offices, background noises such as noise from building systems and equipment, people talking on their phones and music playing outside the building. Whilst some noted that noise gives them the feeling of being at work, a majority pointed out that the noises are distracting and a nuisance. Therefore, workers prefer to have their office away from these sound sources, noise insulation on walls and ceilings and keep doors and windows in their private office spaces closed. Also they like to share offices with fewer co-workers rather than condensed shared and open-plan offices, have flexible workplaces according to tasks and keep conversations outside the office. Whilst many prefer less or no distraction and noise-cancelling headphones, some do not like quiet places. Few workers prefer to have more noise in their workplace and express that they feel at work when hearing inside and outside noises. Also they like to have a little background noise or music in the workplace.

4.6 Control over IEQ factors

We want to point out that respondents had noted the importance of having control over the IEQ factors (thermal comfort, visual comfort, acoustic comfort, ventilation and air quality) in previous questions. Accordingly, the workers were asked about their preferred degree of control over heating, cooling, ventilation, lighting and noise. As such, the findings described below were analysed collectively and further emphasised their desire for control in their workspaces and highlighted the degree of control preferred.

Interestingly, the workers prefer some form of control (Table 8) over full control for all the IEQ factors tested. For lighting, having somewhat control and full control received equal ratings. Also a handful of workers are not interested in controlling the IEQ factors in their workspaces.

5. Discussion

The current study investigated the perceptions and preferences of New Zealand workers on IEQ. This study aimed to identify workers' IEQ preferences for a green indoor environment. Also we aimed to illustrate the effect of demography on workers' preferences using the cross-tabulation χ^2 test of goodness of test.

Our results indicated a range limited to the significant influence of demography on differences in opinions amongst workers across the IEQ parameters tested. For instance, whilst there was an equal distribution of preferences amongst the demographic groups for thermal comfort, all other IEQ parameters tested had some significant differences. Specifically, the type of building accounted for the most significant difference amongst the groups ($p < 0.05$) in preferences for IAQ, lighting system and acoustic comfort. The position of work desks (proximity) also showed significant differences in group preferences for IAQ and type of ventilation, respectively. The preference for the kind of workspace was not equally distributed for the type of ventilation and lighting system ($p < 0.05$). The time spent in New Zealand and age were also not equally distributed for the preferred lighting type. For gender, the preferences were not equally distributed to the kind of ventilation and lighting system and acoustic comfort.

The male workers preferred less noise, whilst females felt no change to the noise levels was required. Unlike the rest of the group sets, those who have spent less than a year in New Zealand wanted a cooler temperature, more fresh air, a mechanical ventilation system and natural lighting in their office spaces. For the noise level, the respondents who have spent the longest time in the country (more than 30 years) reckon they did not need any change in the noise levels in their office spaces. Our findings support previous works that suggest acclimatisation as a proxy for the adaptation to an indoor environment. For example, Schweiker *et al.* (2018) noted the effect of physiological adaptation on thermal perception.

For the type of building and workspace, workers in educational buildings preferred the temperature to be cooler. Those whose work desks were closer to an exterior wall chose natural ventilation. Interestingly, those at the centre of the workspace wanted no change to

Env. control	Mean	Std. Dev	No control (%)	Somewhat control (%)	Full control (%)	Does not matter (%)
Heating	2.2483	0.79616	16.1	49	28.9	6
Cooling	2.2349	0.80025	18.8	43	34.2	4
Ventilation	2.3087	0.88455	17.4	43.6	30.9	8.1
Lighting	2.3289	0.78364	15.4	40.3	40.3	4
Noise	2.2550	0.87112	21.5	38.3	33.6	6.7

Table 8. Control over environmental control

the noise levels. In contrast, those closer to a window or exterior wall preferred less noise in their workspace.

Workers in private offices and those who shared their workspace with a smaller number of people preferred the workspace to be cooler with more fresh air, less noise and natural ventilation systems in their workspace. A notable plausible reason could be that these workers were in workspaces with little or no windows. This finding supports the works of Khoshbakht *et al.* (2021b) and Rasheed *et al.* (2021), who correlated the number of people sharing a workspace to their perception of comfort and productivity. Rasheed *et al.* (2021) investigated office workers' perception of office design and noted that they reported a connection between acoustics improvements and their perceived comfort level. The authors note that workers in individual offices and offices shared by two people show higher subjective comfort satisfaction and better health and productivity than workers in offices shared by 5–8 people and more than 8 people.

Interestingly, our study showed that most of the workers opted for a mixed-mode ventilation and lighting system, as well as no change in the temperature and IAQ in their workspace. However, as depicted in the word cloud of all comments in this study, workers highlight the need for fresher natural air in workspaces (see Figure 1). This supports past works that purport that providing more fresh air in buildings is an excellent way to manage IAQ (Ezzeldin and Rees, 2013). With the current surge in the COVID-19 pandemic, the need for more aerated workplaces, mainly where value depends on face-to-face interactions and collaborations, is expedient. For instance, in a survey of 1,000 adults in the USA, 66% of employees said they were worried about their health in returning to the workplace (Smith, 2021).

Past works evidence workers' preference for a mixed-mode ventilation system. Research shows that a mixed-mode ventilation system increases occupants' satisfaction with IAQ (Amasyali and El-Gohary, 2016; Kosonen and Tan, 2004). Laia *et al.* (2021) noted a potential building cooling demand reduction using a mixed-mode ventilation system reported by past

Figure 1.
Word cloud of all respondents' comments

studies. José *et al.* (2021) observed that a mixed-mode building based on the adaptive comfort criteria could significantly reduce energy use without compromising thermal comfort or IAQ compared to a mechanically cooled building.

Regarding workers' lighting preference for a mixed-mode lighting system, the workers' comments indicate poorly designed lighting systems in their workspaces. Past studies have recommended ideal visual conditions that guarantee acceptable glare levels, contrast, intensity and brightness (Galasiu and Veitch, 2006; Boyce, 2010). Past works have identified physiological and psychological reasons for natural (daylight) preference over artificial light (Rea, 2000; Chang and Mahdavi, 2002; Doulos *et al.*, 2005; Hwang and Kim, 2011). Abdulaali *et al.* (2020) and Boyce (2010) pointed out that daylight exposure helps reduce workers' health problems arising from insufficient artificial lighting levels and increases cognitive performance.

Most of the respondents wanted less noise in their workspace. Past research supports this preference, showing the adverse effects of noise on comfort and productivity (Evans and Stecker, 2004; Hygge, 2003; Balazova *et al.*, 2008). Rasheed *et al.* (2021) found that noise was the only IEQ factor with predictive power for comfort and productivity in office spaces. Other works show that workers in open-plan offices are vulnerable to health, privacy and disturbance issues (Toftum *et al.*, 2012; Jahncke and Halin, 2012; Payne, 2013).

Regarding workers' control over their indoor environment (temperature, air quality, noise and lighting), most workers in our data set noted that they prefer somewhat control but not full control. This could explain why the respondents preferred mixed-mode systems for ventilation and lighting control. Understandably, limiting workers' access to control of the IEQ reduces excessive energy use and enables a more centralised building management system. However, recent works show that smart control mechanisms can balance workers' comfort-driven actions that are not energy efficient (Laia *et al.*, 2021; Amasyali and El-Gohary, 2016; Hosseini *et al.*, 2020) whilst allowing them to control their immediate environment for comfort.

6. Conclusion

This study investigated workers' perceptions and preferences of IEQ and sustainable practices in office buildings. The purpose was to establish more proactive response approaches to occupants' preferences in buildings. To achieve this, this study pursued two objectives: to determine the preferred indoor environmental quality for New Zealand office spaces and highlight the influence of demography and building type on workers' perception of an ideal workspace.

The results from surveying 149 workers show that workers' preferences for an ideal IEQ in green work environments depend mainly on demographics. In general, a significant share of workers prefers their indoor temperature to be neither cooler nor warmer, rich with fresh air, have a mixed-mode operation in terms of ventilation and lighting and be acoustically comfortable with a bit of background noise.

A limitation of this study is that it was conducted in the summer, which could have affected the respondents' perception and skewed the survey results. A study during winter would be complementary for more holistic effects. Also the sample size and location are limited to the populous cities in New Zealand only and may not be representative of the entire country. That said, this study opens the opportunity for more studies in this area of research and highlights significant findings worthy of critical investigations.

The current study is a significant aspect of a larger research programme to develop a standardised evaluation protocol for office buildings in New Zealand. The research programme intends to highlight the importance of users' opinions and interactions with buildings. Further studies will investigate the New Zealand office workers' preference for the design of their facilities.

Notes

1. More information about Qualtrics online survey platform can be found at: https://www.qualtrics.com/au/

Author contributions: "Conceptualization, E.R. and J.R.; methodology, E.R.; investigation, E.R. and J.R.; writing – original draft preparation, E.R.; writing – review and editing, E.R and J.R.; supervision, J.R. All authors have read and agreed to the published version of the manuscript."

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