Perceptions of IEQ, well-being and work performance in work-from-home settings

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Abstract

In India, population growth, demand for housing, and rapid urbanisation have led to higher energy consumption in the building sector. According to the Government of India report, 80% of the buildings that will exist by 2050 are yet to be constructed and a larger percentage is contributed by the housing sector, the population using affordable housing is higher compared to other developed countries. The occupants tend to achieve the desired level of thermal comfort by personal adjustments and mechanical means. Using energy-intensive methods for comfort is not feasible for a country, like India, with a low-energy economy. This study analyses indoor thermal comfort in low income group housing with respect to the building materials and openings used. Two typologies of low income housing were identified - a row housing constructed using conventional materials and a vertical stacking multi-dwelling constructed using Laurie Baker's sustainable construction technology. The first section of the study explores the current scenario of housing based on a thermal comfort field study to understand the current scenario by questionnaire survey and onsite measurements (following ASHRAE class II protocol) and a detailed analysis of the results from the computed data. The second part of the study is software simulation of the existing case with different approaches to improve thermal comfort using design builder simulation. And analysing the results to understand the improvement in indoor thermal comfort with respect to the existing model. From the results, it can be concluded that building material with higher thermal mass can cause a significant reduction in indoor temperatures and PMV thus improving indoor thermal comfort. Passive design strategies to improve indoor thermal comfort with respect to envelope material and openings for future projects at the study area under the low-income housing category, without breaking the concern of cost-effectiveness in affordability, are developed.

Keywords - Indoor environmental quality (IEQ), Work-from-home (WFH), Subjective assessment, Well-being, Work performance, Productivity

1. Introduction

In recent years, a seismic shift has transformed the way we work. The rapid adoption of remote work, catalysed by technological advancements and global circumstances, has redefined the traditional office landscape. As a result, a significant portion of the workforce now finds themselves working from the comfort of their homes. This transformation, while promising newfound flexibility and convenience, has also presented a set of unique challenges and opportunities, particularly concerning the Indoor Environmental Quality (IEQ) within these domestic workspaces.

IEQ encompasses a spectrum of factors, including thermal comfort, indoor air quality, lighting, noise levels, and ergonomics, among others. Traditionally, IEQ has been a focal point in commercial office design, with its direct influence on occupant comfort, health, and productivity well-established. However, the rapid transition to work-from-home arrangements has blurred the lines between professional and personal spaces, making the assessment of IEQ in these domestic environments a pressing concern.

While research on work-from-home (WFH) settings has been conducted since the 1980s, with a focus on behavioral, psychological, and sociological perspectives [1], few studies have evaluated

the IEQ of WFH settings [2]. With the rapid transition to work-from-home arrangements blurring the lines between professional and personal spaces, making the assessment of IEQ in these domestic environments a pressing concern. Several studies have explored the impact of IEQ factors, such as temperature, lighting, noise, air quality, and ergonomics, on work performance and overall health. However, most of the existing research has been conducted in traditional office environments rather than in WFH settings. Understanding the nuanced dynamics of IEQ in the domestic workspace is essential, as it directly influences the quality of life and productivity of a significant portion of the global workforce.

The importance of IEQ on occupant health and well-being has long been acknowledged. Poor IEQ can lead to a range of health issues, including respiratory problems, allergies, and stress-related disorders [3–5]. Conversely, a comfortable and healthy indoor environment can enhance well-being, reduce absenteeism, and increase job satisfaction [6]. Moreover, the link between IEQ and work performance is a topic of increasing interest. Numerous studies have shown that a conducive indoor environment can lead to improved cognitive function, enhanced focus, and increased productivity [7]. In contrast, poor IEQ can have the opposite effect, leading to reduced concentration and decreased job performance [8].

As work-from-home arrangements become more commonplace and are likely to continue even post-pandemic [9,10], understanding the relationship between IEQ and work performance and well-being in these settings becomes imperative. This study is a part of a larger research project that was initiated in March 2022 to systematically evaluate the indoor environmental quality (IEQ) and perceived well-being and productivity of at-home workers. While the project is ongoing, the objective of this study is to present a preliminary analysis of the workers' perception of their work-from-home (WFH) spaces and their impact on work performance and well-being.

2. Methods

Ninety-four study participants (or WFH sites) were recruited through convenience and snowball sampling from Metro Vancouver (Canada) and Seattle Metropolitan (U.S.) regions for a period of nearly two months in the summer of 2022. The inclusion criteria required that participants be working from home for at least two days a week, carrying out sedentary, computer-based work. Individuals planning to move houses, carry out home renovations, or change their working location during the study period were excluded from the study. Each participant was given an indoor, desktop IEQ monitor to be installed in their WFH offices. Results of the preliminary analysis of the monitoring data are published elsewhere [11,12]. A battery of survey items was assembled for subjective assessment of comfort, well-being, and productivity based on an extensive review of survey instruments[13]. The variables of interest being presented in this paper come from a bespoke long-term IEQ assessment questionnaire deployed towards the beginning of the study campaign.

The specific items included in the IEQ questionnaire for this study may be divided into two groups – the features available at WFH spaces and the problems encountered by the workers. Participants were offered a list of 21 features and 15 problems to select the ones relevant for them. These features and problems were related to the five IEQ domains of thermal environment, indoor air quality, visual environment, acoustic environment and physical environment. For this study, the physical environment refers to aspects related to the physicality of the WFH environments, such as furniture or workstation design, work-related equipment (laptop/ computer, monitors, keyboard, etc.), cleanliness, etc. The analysis presents the results based on the assessment of these items on four perception variables – availability (of features) or frequency (of problems), satisfaction (with features), impact on well-being and impact on work performance. A five-point Likert scale was used to rate satisfaction ('extremely satisfied' – 'extremely dissatisfied'), impact on well-being ('not at all' – 'very much') and impact on performance ('enhances a lot' – 'interferes a lot'). Lastly, questions related to overall perception of WFH in relation to satisfaction, well-being and work performance were also included. Data analysis was done in Python using Pandas to process the data and provide descriptive statistics; SciPy for correlation and Chi-square tests; and Matplotlib to create plots.

3. Results

3.1 Subjective assessment of IEQ

At least 50% (n = 47) of the workers had 14 of the 21 features available at WFH. Figure 1 shows the availability of features ordered by the number of participants who reported having access to these features. The most commonly available feature was views to outside (n = 85), followed by enough space to work, access to operable windows, extra monitor, daylight, a clean environment, and ambient light – at least 70% of the workers had access to these features. More than 60% had access to heating, aesthetically pleasing surroundings, and ergonomically designed furniture at WFH. Access to sound privacy, task light, fans, humidifier/dehumidifier was less common.

Figure 2 shows the % distribution of responses across the five satisfaction ratings for the 21 features ordered by the mean rating values. Mean satisfaction ratings were generally high, nearly 4 (corresponding to 'somewhat satisfied') across the features. Workers were most satisfied with the availability of extra monitor for work. In terms of counts, the highest number of 'extremely satisfied' votes were given to views to outside (n = 49), followed by operable windows (n = 40), amount of workspace (n = 37) and daylight (n = 35).

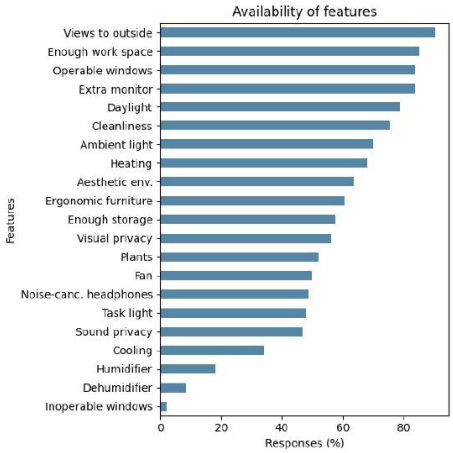

Figure 1: Distribution of responses across IEQ-related features in WFH settings

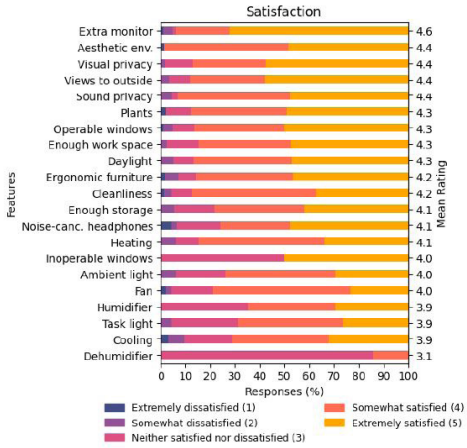

Figure 2: Distribution of responses across satisfaction categories for IEQ-related features in WFH settings

The most widely reported problems pertaining to IEQ in WFH settings were noise from the street (n = 39) and family members (n = 30) (Figure 3). These were followed by the workspaces being either too warm (n = 27) or too cold (n = 26) – interestingly, a majority of workers reported having both issues. Unwanted interruptions were also reported by several workers (n = 20). The occurrence of problems at WFH was rated on a five-point scale as well (always – never). Some of the more

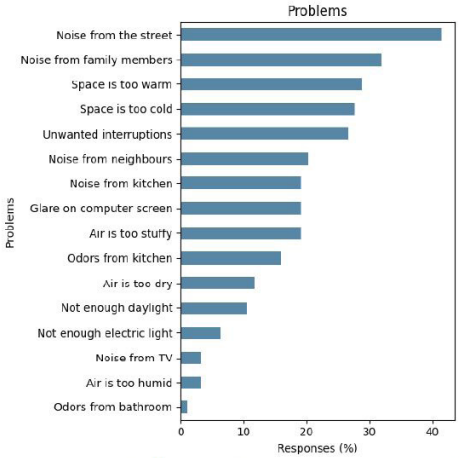

Figure 3: Distribution of responses across IEQ-related problems in WFH settings

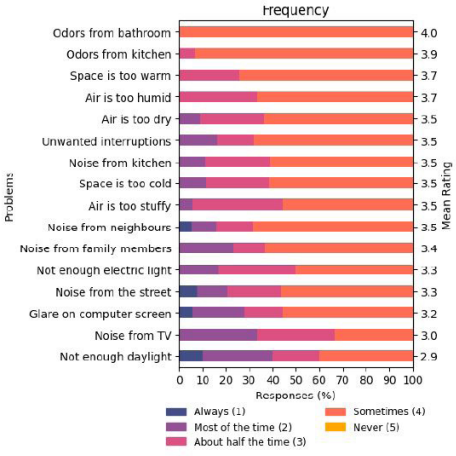

Figure 4: Distribution of responses across frequency categories for IEQ-related problems in WFH settings

frequently occurring problems (between 'always' to 'half the time') were related to disturbances, such as those due to noise from the street (n = 17) and family members (n = 11), or unwanted interruptions (n = 8). Workspace being too cold, too stuffy and glare on the screen (n = 8) were also reported to occur albeit with lesser frequency (Figure 4).

3.1.2 IEQ and work performance

Several features at WFH helped to enhance the work performance – views to outside (n = 76), access to operable windows (n = 72) and enough workspace (n = 73) were the most prominent, followed by availability of daylight (n = 68), clean (n = 65) and aesthetically pleasing (n = 59) environment, heating (n = 58), ergonomic furniture (n = 53), ambient lighting (n = 49) and visual privacy (n = 44). Features such as task light, fans and storage space were deemed less important (n < 40) for work performance (Figure 5).

The problems reported in WFH settings did not seem to affect work performance in general, with the mean ratings across the performance categories never going below 2.8, which is close to performance being affected 'somewhat'. While the number of samples were low, some of the problems most frequently reported to affect work performance were noise from the street (n = 9) and family members (n = 7), unwanted interruptions and the workspace being too warm (n = 7) (Figure 6).

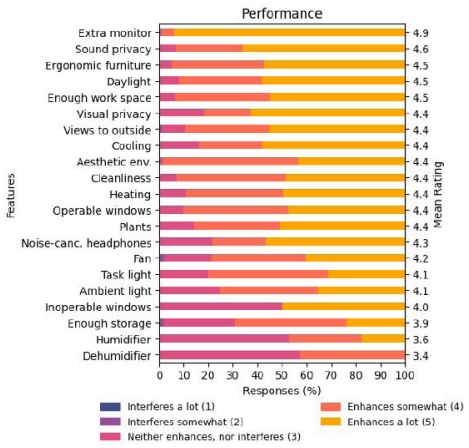

Figure 5: Distribution of responses across performance categories for IEQ-related features in WFH settings

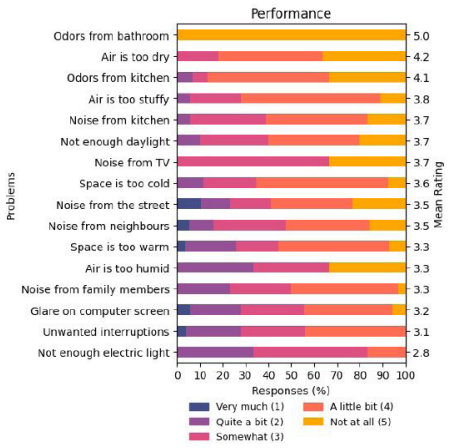

Figure 6: Distribution of responses across performance categories for IEQ-related problems in WFH settings

3.1.3 IEQ and well-being

A view to the outside was the most widely cited feature to affect well-being in WFH settings (n = 66) (Figure 7). The other important features were access to operable windows (n = 60), extra monitor (n = 60), daylight (n = 55), enough workspace (n = 53) and cleanliness (n = 49). For at least 12 features on the list, the mean rating on the well-being impact scale was at least 4, which indicates that these features affected well-being 'quite a bit'. The problems that most affected well-being were noise from the street (n = 27) and family members (n = 23), and unwanted interruptions (n = 15), followed by workspace being too warm (n = 15) and noise (n = 14) and odors (n = 13) from the kitchen. As in the case of performance, the effect of these problems on well-being ranged between 'somewhat' and 'a little bit' in terms of the mean ratings (Figure 8).

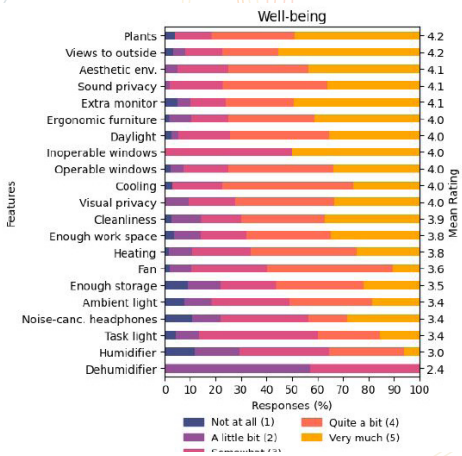

Figure 7: Distribution of responses across well-being categories for IEQ-related features in WFH settings

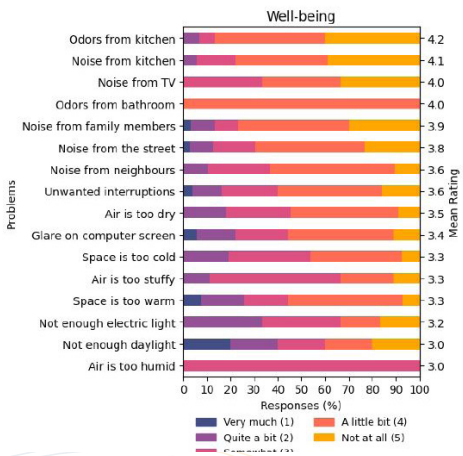

Figure 8: Distribution of responses across well-being categories for IEQ-related problems in WFH settings

3.2.4 Overall assessment of WFH

Nearly 80% of the workers felt their work performance was enhanced somewhat or a lot when they WFH while only than 9% said WFH interfered with their performance (M = 4.1). Satisfaction with overall workspace was also high with almost 89% being somewhat or extremely satisfied and less than 8% expressing dissatisfaction (M = 4.2). The scale used for the assessment of well-being indicated only if the workers were affected by the overall workspace and it did not show the direction of that impact in terms of whether it was positive or negative. Less than 52% said their overall workspace affected their well-being while nearly 23% did not report much difference in their well-being as a result of WFH (M = 3.4).

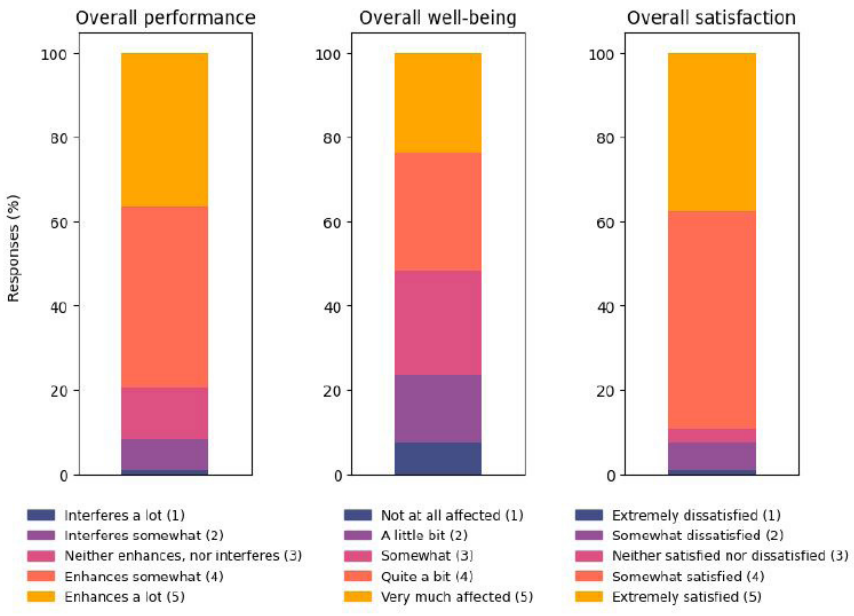

Figure 9: Distribution of responses across overall performance, well-being and satisfaction categories in WFH settings

Spearman's rank correlation was used to measure the strength and direction of the monotonic relationship between overall well-being, work performance and satisfaction (Table 1). Performance and satisfaction showed a strong positive correlation (r_s (91) = .63, $p < .001$), indicating that as the performance at WFH increases, overall satisfaction with WFH also tends to increase. Performance and well-being showed a moderate positive correlation (r_s (91) = .26, $p < .05$), suggesting that as

the performance at WFH increases, overall well-being while WFH also tends to increase. Well-being and satisfaction had a weak positive correlation (rs (91) = .20, p = .053), implying that there is some positive relationship between overall well-being and overall satisfaction with WFH, but it is not very strong.
A chi-square test of independence was also performed to examine the association between overall well-being, work performance and satisfaction (Table 1). The relation between overall performance and well-being was significant, $\chi 2$ (16, N = 93) = 50.45, p < .01. Similarly, the relationships between performance and satisfaction ($\chi 2$ (16, N = 93) = 146.42, p < .01), and well-being and satisfaction ($\chi 2$ (16, N = 93) = 28.78, p < .05) were significant as well although the latter was less strong.

Table 1: Outcomes of correlation and Chi-square tests between overall performance, well-being, and satisfaction

	Performance	Well-being	Satisfaction
Performance		50.45***	146.42***
Well-being	0.26*		28.78*
Satisfaction	0.63***	0.20	

Spearman's rho (r_s), chi-square (χ^2)
*p<.05, **p<.01, ***p<.001

4. Discussion

The preliminary analysis of subjective assessment of IEQ in WFH settings and its perceived impact on work performance and well-being revealed some interesting insights into the home-office environments of Canadian remote workers. The most prevalent features available to them in their workspaces were views to outside, operable windows, daylight and enough space to work. In addition to being the features with which most of the workers expressed satisfaction, they appear to affect workers' work performance and well-being. The problems most frequently experienced by workers were related to disturbances due to noise from the street and family members, and unwanted interruptions. Curiously, these problems seemed to affect workers' well-being more than they affected work performance.

The generally high ratings for satisfaction, work performance and well-being observed in this study also resonate with the new, albeit sparse, IEQ research in similar settings. These studies report medium to high satisfaction with the thermal environment [14–17], and high satisfaction with the air quality [14–20] and visual environment [21–24]. On the other hand, annoyance with noise was high in WFH settings and found to be detrimental to well-being [25] and work performance, especially compared to the pre-lockdown context [26,27] and compared to other IEQ domains [16,28,29]. This aligns with the noise complaints and their affect on well-being and work performance reported by the workers in this study.

There are two important themes to draw from these results. The first is the relatively understated role played by some of the otherwise significant factors from published research on IEQ – those related to the thermal environment. While this study underscores the significance of operable windows, which could potentially be related to thermal comfort, it is notable that it doesn't place as much emphasis on other factors directly associated with this domain. This suggests that operable windows might be serving a different purpose, possibly akin to the role played by outside views. It is rare to not have a heating system in Canadian residences and many existing and new buildings are being fitted with cooling as well. WFH also allows more personal control over the setpoint, potentially resulting in optimal thermal conditions, or at least, better acceptance to these conditions as a result of behavioural adaptation – clothing, metabolic rate and lifestyle habits.

This leads to the second prominent theme in the study's findings – the emergence of factors tied to the physical and acoustic environment. These factors encompass aspects such as the presence of scenic views, the available workspace area, aesthetics, cleanliness, on the one hand, and the challenges linked to noise and interruptions on the other. In the burgeoning field of research on IEQ in WFH settings, we observe a similar emphasis on the acoustic and physical surroundings. This emphasis may be attributed to the fact that workers have relatively less control over factors associated with these domains compared to others. For instance, mitigating noise originating from the street is primarily achieved by closing windows, a step that is likely to have a distinct impact on performance and well-being. Similarly, the containment of noise and unwanted interruptions stemming from family members can be a challenging task. Concerning the physical environment, there exist inherent limitations regarding the extent to which workspace improvements can be made, and in cases where space is insufficient, addressing such limitations becomes a formidable challenge.

5. Conclusion

This paper presented an analysis of the subjective assessment of indoor environmental conditions in WFH settings and the perceived impact of these conditions on work performance and well-being, based on a field study in the Pacific Northwest region involving 94 participants conducted during summer of 2022. The most prevalent features available to the workers in their workspaces were views to outside, operable windows, daylight and enough space to work. In addition to being the features with which most of the workers expressed satisfaction, they appear to affect workers' work performance and well-being. The problems most frequently experienced by workers were related to disturbances due to noise from the street and family members, and unwanted interruptions. These problems affected workers' well-being more than they affected work performance.

A majority of workers reported their work performance was enhanced while WFH (M = 4.1) and satisfaction with overall workspace was high (M = 4.2). Significant correlations were found between satisfaction and performance and between well-being and performance.

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