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Understanding the effects of timber rich workplaces on occupants perceived productivity and health: a pilot study

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Leveraging the inherent connection people have with nature through the implementation of biophilic design principles is not new. Research has documented how the incorporation of natural finishings (including timber), daylight and greenery can boost workers' creativity, productivity whilst curbing stress. Despite the body of work, a recent meta-analysis of 49 studies shows that there is a prevalence of (i) confounding factors, (ii) university students as the primary demography and (iii) limited use of quantitative methods to analyse data. This study contributes to this knowledge gap by exploring the effect of timber-rich workplaces on occupant perceived productivity and health. By concentrating on timber, a material of great prevalence within Australian workplaces, this study illustrates the feasibility quantitative methods when investigating the biophilic design effects on people whilst testing a mixed-method blueprint for experiments to be conducted in workplaces. To do this a novel mixed-method pilot study of quantitative survey and biomarkers (i.e. hair cortisol) was deployed in a real-world field experiment setting that included (n = 23) office worker participants working in and then moving from a concrete office space to a timber-rich office space. Results indicate that, following the move, participants reported higher comfort, well-being, and productivity. Analysis of our cortisol data showed lower average stress levels after moving to the timber rich setting (before Mean = 317.200 pg/mg or log(5.33) and three months after Mean = 286.421 pg/mg or log(5.23). That is, office workers had lower cortisol (i.e. lower stress levels) after moving from the concrete office space into the timber office space. Our study provides preliminary quantitative evidence that timber-rich environments provide a viable means to positively influence occupant wellbeing, comfort and productivity. That said, based on the studies small sample size and other limitations the authors caution generalizability of key findings relating to any observable changes. Rather, as the prevalence of timber rich workplaces increases in construction, this study should be seen as a first of its kind pilot study and opportunity for future research into office worker wellness and productivity.

Keywords Timber rich workplace, Healthy office space, Wellbeing and productivity, Biomarkers, Biophilic design, Hair cortisol

For millennia, human biological and cognitive processes have evolved within what Kellert et al. 2013[1] describe as a 'sensorially rich world' that underpins social, environmental, biological, and psychological life-sustaining systems. Nature, in all its diverse forms and expressions, has been a key driver of this evolution. The biophilia hypothesis captures this relationship, positing that humans have an innate affinity for nature and are genetically and biologically predisposed to need natural elements in their lives[2]. As such, amid challenges such as climate

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change, environmental degradation, a technologically-focused society, and a global population that spends approximately 95% of its time indoors[3], the need for biophilia has never been more crucial.

Emerging from this context is the concept of biophilic design (BD), which is founded on the biophilia hypothesis and seeks to 'create good habitats for people as biological animals'[4]. BD in the indoor environment will typically have physically present naturalistic features and/or representations of natural characteristics expressed via images, sounds and other sensory stimulants. Multiple benefits are associated with improving the human-nature connection through BD, with positive impacts to measured and self-reported physiological, psychological, and productivity metrics. From the perspective of occupants and indoor environment quality, biophilic design—and biophilia more broadly—has been shown to enhance mood, reduce stress, and improve productivity, psychological well-being, and overall satisfaction[5–8]. More recently, office fit-outs designed with biophilic design principles have also been linked with higher utilisation performance[9].

Despite the growing body of work dedicated to report on positives outcomes of implementing biophilic design principles within spaces, a recent meta-analysis focusing on 49 studies[10] showed that within the current knowledge base there are considerable limitations. Authors noted the presence of many confounding factors within study designs and analysis, the pronounced number of studies recruiting university students as their primary demography, and limited adoption of quantitative methods and analysis. Combined, these three main limitations of current studies limit the ability to draw accurate conclusions from the effect of adoption of biophilic design principles more broadly, particularly within settings.

Within the biophilic design umbrella, timber emerges as a popular choice either as a material, finish, and/or texture used in workplace fit-outs. As a renewable material that has several evidenced benefits for both the natural environment and building occupants[11], with the drive to include biophilic elements such as timber having received widespread attention. Despite the prevalence of timber in contemporary office fit outs in Australia, there is limited research examining the relationship between timber-rich environments and occupant outcomes in workplaces. Additionally, few studies take a holistic approach by examining the relationship using both quantitative survey (e.g., post-occupancy evaluations) and biological marker measures of these outcomes. Investigating the impact of individual biophilic elements, such as timber, is critical for guiding future design practices, fit-out specifications, and research directions. Furthermore, given the interconnections between material selection and other environmental performance metrics—such as life cycle carbon, land-use change, and resource depletion, which have arguably received greater attention—it is essential to ensure that specified materials contribute effectively to all dimensions of environmental performance. This includes considering measures that impact occupants.

Considering gaps in biophilic design research—and focusing on timber, a prevalent material in Australian workplaces—this field pilot explores quantitative methods to examine associations between timber-rich interiors and office-worker outcomes. We use paired survey data and biomarker measurements to characterize changes in self-reported wellbeing, comfort, and productivity following a move to a timber-rich office; the observational design is not intended to establish causal effects, and with a small sample some endpoints do not reach statistical significance. By documenting methods and preliminary signals, the study contributes preliminary evidence and may inform subsequent, more rigorous investigations that could ultimately guide human-centered design and procurement.

Background

Society currently spends a substantial portion of their daily lives in the workplace. Consequently, the significance of workplace design has emerged as a pivotal concern for organisations due to the established relationship between design and employee wellbeing, productivity, health, and comfort[7,12]. Over the past decade, the importance of workplace design has garnered even greater attention as organisations embark on a 'flight to quality', seeking commercial tenancies that embody high-quality experiences, amenities, sustainability objectives, and occupant wellbeing[13]. BD and its constituent principles can contribute to these high-quality environments. Research has shown that BD in the workplace can lead to cognitive advantages, occupant comfort, and enhanced psychological outcomes[14]. Through the integration of physical connections to nature, sensory elements, natural materials, or virtual natural experiences, productivity can be boosted, psychophysiological stress can be mitigated, and/or occupant mood can be elevated[14–17].

Approaches to BD vary depending on the scale and typology of the project. In Zhong et al.[22] comprehensive review of BD in architecture, the authors summarised three key design approaches that can be implemented—nature incorporation, nature inspiration, and nature interaction. Within these three key design approaches, the authors highlighted 18 elements that could be introduced, ranging from plants and natural patterns to geometric forms and principles of complexity and order. The integration of natural materials, such as timber, is one such key design element or strategy for integrating BD into architecture[4,18]. Other methods, such as daylight, views, or connections to nature, are often subject to favourable site and context conditions[19], whereas natural materials are more context-agnostic, making it a relevant strategy for both new builds and retrofits. Furthermore, timber—as a natural, renewable, comparatively low-carbon, reusable material—has the co-benefit of being able to help mitigate the significant contribution of the building sector to global greenhouse gas emissions[20]. From the perspective of workplace design, the utilisation of timber encompasses a diverse range of applications. Timber can serve as a structural material as part of a mass timber construction approach, while it may also contribute to interior surface finishes and fixtures and fittings. The inherent versatility of timber facilitates its incorporation into workplace design across a range of scales.

Limited research has examined the relationship between timber as a BD element and human-centred factors of the occupants experience, including wellbeing, comfort and productivity. Whyte et al. 2024[11] discuss some of this evidence in the context of mass timber construction (MTC), highlighting Nyrud and Bringslimark 2010[21] review of the psychological impacts of timber-rich environments, which indicated occupant preferences for wood due to its natural qualities. Alapieti et al. 2020[22] reviewed the physiological effects of timber and found that timber-rich environments may reduce stress responses compared to non-timber environments. However, study limitations of the literature reviewed raise doubts about whether this effect could be consistently replicated. Timber-rich environments have been demonstrated to affect occupant attention recovery[23], induce feelings of warmth and intimacy in occupants[24], and affect cerebral activity of building occupants[25]. Research has also used restorative theories, such as Attention Restoration Theory (ART) and Stress Recovery Theory (SRT)[26] to explore the relationship between timber and occupant outcomes. These theories—SRT and ART—suggest that natural environments help restore an individual's psychological and physiological resources that may be depleted by stress, mental fatigue or overstimulating environments. However, as Burnard and Kutner 2015[26] illustrate, further research is required to understand the dynamics between timber exposure and occupant responses.

Upon examining studies that have explored the relationship between biophilic elements (such as timber) and occupant wellbeing, comfort and productivity, patterns in their methodological approach and particular limitations emerge. In the assessment of biophilia responses, studies were found to use methods such as immersive virtual reality environments[7,8,17,27], laboratory-based evaluations[28,29] and experiments where participants were exposed to visual or olfactory stimuli[30,31]. However, studies in which participants are situated in actual office environments, thereby providing an authentic representation of real-world workplace settings are extremely limited[9,11]. The importance of examining this issue within real-world workplaces is critical, as there are several moderating variables, such as location, office layout, climate, privacy[32], that can affect an occupant's experience and satisfaction. Controlled laboratory experiments may overlook this complexity, making it essential to also pursue research grounded in an actual workplace environment to generate practically relevant and applicable insights.

Finally, understanding of biophilia perceptions is most often gained through self-reported measurements, such as surveys or focus groups[15,16,33,34]. The increasing availability of health monitoring technology, along with a growing interest in occupant health and wellbeing, has recently led to the use of key biomarkers such as heart rate, blood pressure, brainwave activity, and cortisol levels to assess the effects of biophilic elements in built environments[17,35,36]. Building on this research foundation, we adopt an exploratory mixed-methods approach to examine associations between biophilic elements—such as timber—and office workers' self-reported wellbeing, comfort, and perceived productivity, offering a preliminary, complementary perspective on timber-rich workplaces.

Materials and methods

To examine changes associated with relocation to a timber-rich workplace across occupant wellbeing, comfort, and productivity, we conducted a field experiment using a mixed-methods approach. While working in a real-world office provides practical relevance, because of small sample size, observations were not controlled (no randomization or environmental measurements), so findings should be interpreted as associative and exploratory rather than causal. By timber rich environment, this study draws on BD principles in workplace environments as outlined by Avazpour et al. 2025[9]. It refers to a workspace where natural timber is prominently used across architectural and interior elements, such as walls, ceilings, furniture, and finishes, as part of a broader application of BD strategies. This includes visible wood surfaces, natural textures and warm tones that creates a sensory connection to nature. In the context of this study, the timber rich office setting features a high proportion of exposed timber along with an access to natural light and greenery, creating a nature-inspired interior intended to support office workers' wellbeing. A more detailed comparison of the material and spatial characteristics of the timber-rich and non-timber environments is provided in Section "Setting—office location".

That said, it is important to clarify that this is a pilot study that followed participants transitioning from a concrete office setting (first observation) to a timber rich office setting (second observation—three months later). Our method provides for a unique experimental field based setting, but does not have or provide a control group, as would be the case for a randomised control trial (RCT). Consequently, causal inference is not supported, and any pre–post differences should be interpreted as associations rather than effects of timber per se. Opportunities to run controlled or multi-site studies were limited by the small number of comparable timber-rich offices currently available in Australia. We present this work as a pilot intended to inform the design of future controlled and multi-site studies as timber-rich workplaces become more prevalent in Australia and globally.

Self-reported questionnaire

To assess the human and organisational benefits of timber-rich environments, we developed a survey tool based on previously validated measures[11]. The survey was structured into four sections. The first section collected basic personal information, focusing on demographic and socioeconomic indicators. The second section explored participants' attitudes and preferences towards building design, including their perceptions of the Indoor Environmental Quality (IEQ) and questions related to potential health-related symptoms that participants experienced. These data were collected as participant stated preference only, as the study (due to restrictions based on the office spaces being leased by private businesses) was not able to collect any longitudinal onsite environmental variable data (e.g. ventilation, acoustics, etc.). The third section gathered data on participants' work experience and health status, including physical and mental health, as well as health-related behaviours such as physical activity, sleep, smoking, and alcohol consumption. Building on the framework of the previous survey (Whyte et al., 2024), the fourth section was added to better understand participants' feelings at work and their feelings toward their work environment, measured through the work and wellbeing (UWUS) and CASBEE-Office Health checklist.

Hair cortisol

Cortisol is a hormone produced in the adrenal gland which regulates blood sugar, blood pressure, and the body's immune system. It is often referred to as the "stress hormone", because levels decrease or increase with physical, psychological or emotional stress. Cortisol can thus be measured as a biological marker for use in behavioural research, and can be collected and analysed in saliva, urine or hair samples[11]. The use of participant hair cortisol collection and analysis as a biomarker provides a novel objective and standardised robustness check for our subjective quantitative survey data collected.

For the current study, cortisol was analyzed from approximately a fingernail sized patch of hair cut (as close to the scalp as possible to capture as much recent cortisol exposure as possible) from the back or top of the heads of our study participants on two separate occasions, approximately three (3) months apart (August–November 2025). Sample preparation and analysis using ELISA was based on the protocol by Stalder et al. 2017[37] with minor modifications. Briefly, the hair samples were washed three times for 5 min with 2.5 mL isopropanol and left to dry overnight. Then, the hair samples were weighed (approximately 5 mg), frozen in a -18 degrees freezer overnight and then ground in a bead beater with 3.2 mm stainless steel beads for 3 min. The samples were then incubated with 1 mL methanol at room temperature for 24 h in a rotator. One mL supernatant was transferred into a new vial and put in a 52 degrees incubator overnight for evaporation. Then 0.2 mL phosphate-buffered saline was added, the samples were vortexed for 30 s and analysed with a commercial immunoassay. The analysis was carried out at the laboratory at James Cook University, Townsville, Australia.

Setting—office location

The study was conducted at the T3 Collingwood site, located at 36 Wellington Street, Collingwood, Victoria, Australia. T3 Collingwood stands as one of Australia's largest multi-storey mass-timber buildings, with 9 out of its 15 floors built using this material (as seen in Fig. 1a,b). The building features a distinctive exposed glulam post-and-beam framework and cross-laminated timber panels for the floors. This setting provided a naturalistic context to observe associations related to an office relocation from predominantly concrete interiors to a timber-rich interior (including timber wall panels, flooring, and furniture). Prior to relocation, participants worked in offices with polished concrete floors, interior columns, beams, and ceilings.

Participants

A total of 51 surveys and cortisol samples were collected from 26 unique individuals. Participants were recruited from two large commercial organisation. Participant organisations were selected based on their workplace changing from concrete to timber rich workplace environments during the study period. All participants were remunerated $50AUD for participation in the study at both stages.

The sample in this study consisted of a balanced gender distribution, with 50% of the participants identifying as female and 50% identifying as male. Of the total participants, the majority were full-time permanent workers (87%) that reported a job tenure of between 1 and 3 years (64%). Most participants were aged between 18 and 34 years (51.0%), followed by those aged 35–55 years (43%), and those aged 55 and above (6%). This age distribution reveals a relatively balanced spread of participants across different age groups, with the largest proportion of participants in the younger age categories (24–29 years) and a notable representation of individuals in the middle age groups as well.

Most participants held a bachelor's degree (74.2%), with a smaller proportion having completed postgraduate studies (16.1%) or having qualifications below tertiary level (9.7%). Regarding work hours, most participants worked 31–40 h per week (75.0%), with a smaller group working 41 or more hours per week (25.0%). In terms of office work hours, the majority worked less than 25 h per week in the office (63.3%), while 23.3% worked 25–35 h, and 13.3% worked more than 36 h in the office.

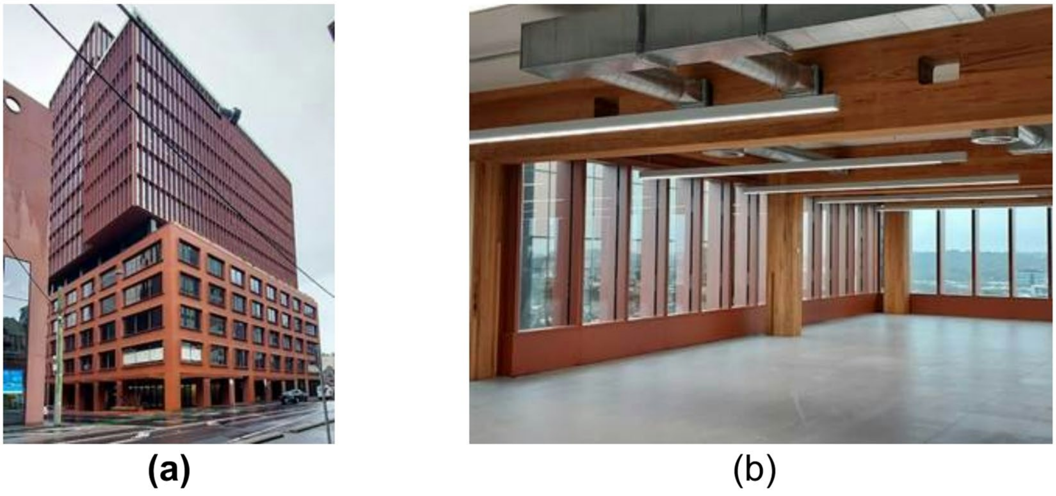

Fig. 1. (**a**) T3 Collingwood, Melbourne Australia; (**b**) Mass Timber Floor- Level 7.

Data collection

The field experiment took place between June and October 2024. The first round of data collection was conducted across June and July 2024. During this round, participants were located in concrete workplaces and completed a hard copy survey alongside providing a hair sample. The second round of data collection took place across September and October 2024. During this round, all participants were now working in timber-rich workplaces, and were again given the same hard copy survey and a second hair sample was collected. This design allowed for a comparison of participants self-perceived (i.e. survey) and biological (i.e. cortisol) results of the differences between the two workplace environments, focusing on the effects of the (timber rich) change in the indoor environment on factors such as productivity, work satisfaction, and overall well-being.

All data collection (i.e. both survey and hair cortisol) was conducted in accordance with the projects 2023 Queensland University of Technology Human Research Ethics Committee Approval—no. #6765. All study subjects provided written informed consent prior to participation.

Analysis

Descriptive and comparative analysis

Descriptive statistics were used to assess the overall comfort, productivity, and health of participants in both office environments, as well as to map the characteristics of participants from both the timber and non-timber groups. In preparation for analysing responses from the self-reported questionnaire, text-based responses were converted into numeric or categorical variables where applicable. T-tests were performed to compare differences between the two groups (timber-rich versus non-timber workplaces). Then descriptive analysis was conducted to evaluate participants' overall comfort, perceived productivity, and health in each setting.

Multivariate regression analysis

Our study employs ordinary least squares (OLS) regression analysis using STATA 17 to examine the relationship between biophilic design elements in office buildings and key workplace outcomes. Four separate regression models were estimated, each corresponding to a distinct dependent variable: (1) Impact on Productivity from Environmental Conditions (7-point Likert scale), (2) Impact on Productivity from the Entire Office Building (7-point Likert scale), and (3) Work Engagement and Performance (8 questions on a 5-point Likert scale). To prepare the data for regression analysis, two dependent variables (3) and (4), were transformed by computing the average response for each respondent. Since these variables were originally collected using a hard copy survey format, averaging across the respective survey items allowed for their use as dependent variables in the specification models. Sixteen independent variables were included across all specifications: a Timber dummy, Cortisol levels, Age (continuous), Male dummy variable for sex, Single dummy variable for marital status, Annual income (ordinal variable), Postgraduate dummy, Building Image Rating, Interior Aesthetic Rating, Overall Comfort Rating, Perceived Health in the Building, Life Satisfaction, Perceived Overall Health, and three composite measures—Feelings about the Company, the Work & Well-being Survey (UWUS), and the CASBEE-Office Health Checklist—each of which was averaged across its respective survey items for each respondent. The CASBEE-Office Health Checklist was assessed through two components: 1. Fulfilment of Positive Factors (9 questions on a 4-point Likert scale, from 0 = strongly disagree to 3 = strongly agree) and 2. Elimination of Negative Factors (7 questions on a reverse-coded 4-point Likert scale, from 0 = often to 3 = never). It is noted that to create a single measure, responses from both components were averaged, maintaining the original Likert scale direction for each type of question. Statistical significance was evaluated at the 0.1%, 1%, 5%, and 10% levels, with robust standard errors applied to account for potential heteroskedasticity.

Results

Satisfaction with indoor environmental quality (IEQ)

Analysis of satisfaction with various aspects of the indoor environment, including temperature, air quality, lighting, and acoustics, indicated higher satisfaction in the timber-rich workplace across all factors (see Fig. 2). Participants in the timber-rich office generally reported higher satisfaction with IEQ factors compared to those in the non-timber office. Dissatisfaction with temperature was lower in the timber-rich office (15%) compared to the non-timber office (19%). Therefore, there was a significantly higher proportion of timber-rich participants (85%) that reported their satisfaction with the temperature. In contrast, only 68% of non-timber participants were satisfied. This represents a relative increase of + 25% in satisfaction with temperature.

Self-reported Air quality showed a minimal disparity with 13% of non-timber participants dissatisfied when compared to 10% in timber-rich spaces. More participants in the timber-rich office (80%) reported satisfaction with air quality compared to 74% in the non-timber office. This reflects a + 8% increase in satisfaction with air quality. The lighting in the timber-rich office was rated more positively (5% dissatisfied participants) when comparing to 16% of non-timber participants. This translates to a + 20% increase in their satisfaction.

Additionally, acoustic satisfaction was notably higher in the timber-rich office, where only 10% were dissatisfied, compared to 57% in the non-timber setting. This shows an impressive + 117% increase in acoustic satisfaction in the timber-rich office. When it came to overall IEQ satisfaction, none of participants in the timber-rich office were dissatisfied (i.e., rated it between 1 and 3), whereas 10% of non-timber participants expressed dissatisfaction. This reflects a + 9% increase in overall satisfaction for the timber-rich office. These findings suggest that timber-rich offices generally offer a more favourable environment, particularly in terms of air quality, temperature, and acoustics, contributing to higher overall satisfaction among participants. The results showed that the timber-rich office had a higher average satisfaction score, reflecting a more positive assessment of the environmental conditions.

Fig. 2. Distribution of user satisfaction with IEQ of the building.

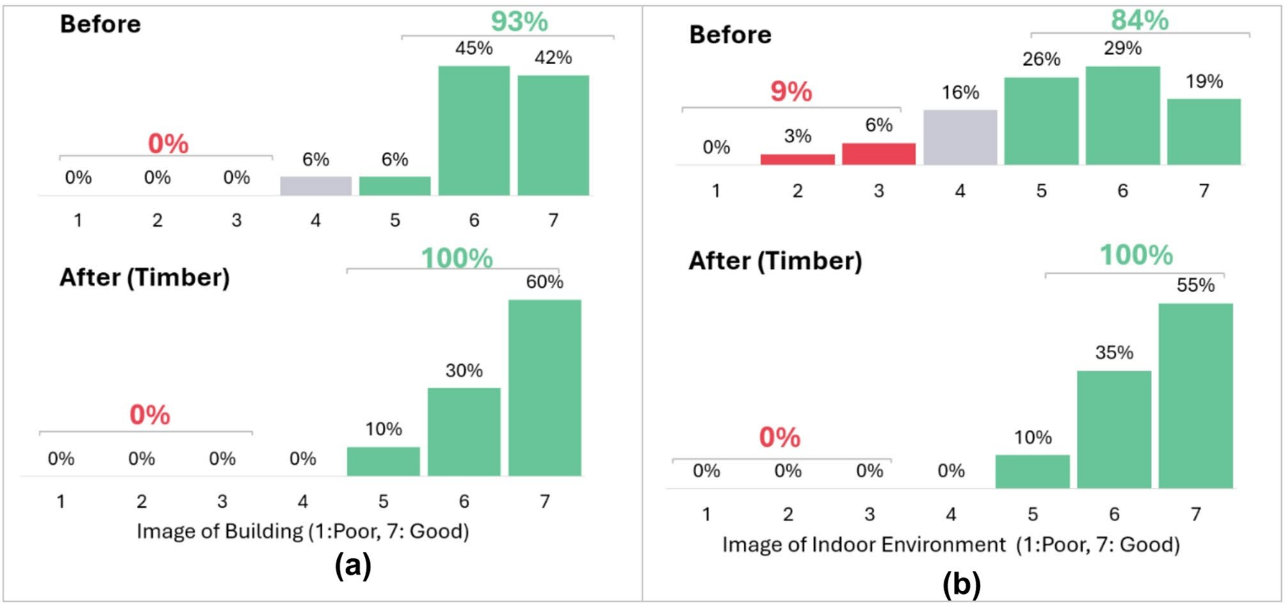

Fig. 3. Distribution of user satisfaction with (**a**) image of the building and (**b**) image of the indoor environment.

Satisfaction with physical environment

Participants were also asked to assess the image of the building and the image of the indoor environment (see Fig. 3). The results show a generally more favourable perception of the image of the building among participants in timber-rich office compared to those in non-timber office. A strong 60% of participants in the timber-rich group rated the image of the building as highly positive (7), while 42% of non-timber participants gave the same rating. Additionally, 30% of participants in timber-rich buildings rated the image as a 6 compared to 45% in non-timber environments. This suggests that all the participants were satisfied in timber-rich while 6% of the participants in non-timber office were neither dissatisfied nor satisfied. Nonetheless, neither group viewed the building's image negatively. These findings suggest that timber-rich buildings are more likely to leave participants with a highly favourable impression, potentially due to the aesthetic and psychological benefits commonly associated with natural materials like timber.

When rating the image of the indoor environment, 55% of participants in the timber-rich office rated it as 7 (good), compared to only 19% in the non-timber office. The non-timber office had a higher proportion (16%) rating the indoor environment as a 4 (neutral), while no timber-rich office participants gave the same rating, indicating higher satisfaction with the indoor environment in the timber-rich workplace.

Satisfaction with impacts of building on perceived health and productivity

Regarding participants' perceived health, the results showed that those in the timber-rich workplace reported higher rates than those in non-timber setting (see Fig. 4). No participants in the timber-rich group reported feeling less healthy, while 16% of participants in the non-timber group indicated they felt less healthy. Around 30% of participants in both groups felt neutral. However, a higher number of participants in the timber-rich office, 70% rating their health as 4 or higher, compared to 52% of participants in the non-timber office who rated their health less than 6 with none rating it as 7.

In terms of productivity, participants were asked to rate the impact of their working environment on their productivity with responses ranging from a decrease of 30% or more to an increase of 30% or more. The results showed that 45% of participants in timber-rich environments reported a high increase in productivity (20% or more) while this indicator was 26% in non-timber environments. It is worth noting that 75% of participants in timber-rich environments reported an increase in productivity, which was 32% more than those in non-timber office. In terms of high productivity, participants in timber-rich environments reported nearly twice as much productivity increase, while in terms of low productivity, they reported half the rate of decrease compared to those in non-timber environments.

Workplace satisfaction in timber vs. non-timber offices

To understand whether there is any difference between satisfaction of different aspects mentioned in descriptive analysis, t-tests were undertaken. Table 1 shows the means and standard deviations of the aspects related to the physical environment for timber-rich and non-timber workplaces. It also shows the comparison between the mean scores and their significance and effect sizes for these settings. The analysis describes the evaluation of participants' perceptions of various environmental factors which includes the overall image of the building, temperature comfort, air freshness, lighting, noise, health, and overall comfort. The results indicate significant differences in certain factors, while others showed no statistically significant variance between the two office settings.

Participants working in timber-rich offices reported significantly higher satisfaction with temperature conditions (Mean = 5.50, SD = 1.28) compared to their counterparts in non-timber offices (Mean = 4.81, SD = 1.42), with a mean difference of 0.69. This difference was statistically significant ($p = 0.00$), and the effect size (Cohen's D = 0.80) suggests a moderate to large effect. This indicates a notable difference in temperature satisfaction between the two groups. However, when it comes to artificial lighting, the results showed the opposite trend. Participants in timber-rich offices rated the quality of artificial lighting lower (Mean = 4.20, SD = 0.52) than those in non-timber offices (Mean = 4.77, SD = 0.92) showing a mean difference of -0.57. This difference was statistically significant ($p = 0.01$) and the effect size (Cohen's D = 0.81) shows a large effect. This suggests that the quality of artificial lighting was perceived more negatively in the timber-rich offices. One possible explanation for the lower satisfaction with artificial lighting in timber-rich offices is the design focus on maximizing natural light, which may reduce the emphasis on artificial lighting. While artificial lighting in timber-rich spaces may not have been as highly rated, the positive effects of natural elements like daylight, temperature comfort, and air quality were significant, contributing to higher overall satisfaction, health and productivity. These natural elements likely outweigh the perceived shortcomings in artificial lighting which emphasise the overall benefits of timber-rich environments.

In terms of glare from natural light, employees in timber-rich offices reported significantly higher levels of satisfaction (Mean = 5.11, SD = 1.70) compared to those in non-timber offices (Mean = 3.61, SD = 1.80) with a substantial mean difference of 1.50. This difference was statistically significant ($p = 0.01$) along with a large effect

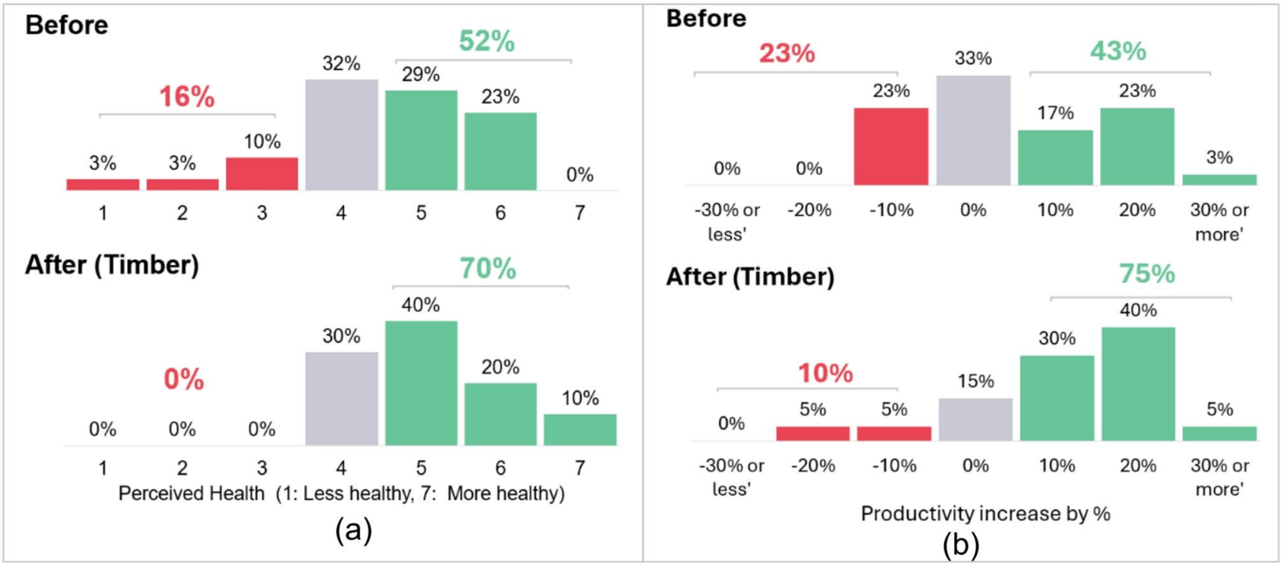

Fig. 4. Distribution of users' (**a**) perceived health and (**b**) productivity in the building.

	Satisfaction with …	Non-timber		Timber-rich		Mean difference	Significance	Effect size (Cohen's D)
		Mean	Std dev	Mean	Std dev			
Building Image	How do you rate the image that the building as a whole present to visitors?	6.17	0.85	6.50	0.69	0.33	Not significant	–
Thermal perception	How would you describe the temperature and air conditions in your work area over the past three months?	4.72	1.51	5.20	1.36	0.48	Not significant	–
Temperature satisfaction		4.81	1.42	5.50	1.28	0.69	0.00	0.80
Air humidity		5.03	1.55	5.40	1.14	0.37	Not significant	–
Air smell		2.61	1.61	2.35	1.46	-0.26	Not significant	–
Air freshness		3.71	1.55	3.85	1.42	0.14	Not significant	–
Artificial Light	How would you describe the quality of the lighting in your normal work area?	4.77	0.92	4.20	0.52	-0.57	0.01	0.81
Overall lighting		5.26	1.46	5.70	1.26	0.44	Not significant	–
Glare from light		3.74	1.69	3.30	1.78	-0.44	Not significant	–
Glare from sun		3.61	1.80	5.11	1.70	1.50	0.01	0.86
Daylight		3.77	1.36	5.00	1.26	1.23	0.02	0.95
Noise outside	How would you describe noise in your normal work area?	3.70	1.15	3.25	1.07	-0.45	Not significant	–
Noise inside		3.70	1.38	4.20	0.89	0.50	Not significant	–
Acoustic		3.60	1.73	5.35	1.31	1.75	0.00	1.14
Décor layout	How do you rate the image that the indoor environment (e.g., décor, layout) as a whole present to visitors?	5.24	1.33	6.45	0.69	1.21	Not significant	–
Overall Comfort	All things considered, are you satisfied with the overall comfort of the building?	5.61	1.05	6.20	0.77	0.59	0.00	0.84
Health	Overall, do you feel less or more healthy when you are in the building?	4.48	1.27	5.05	0.97	0.57	0.01	0.82
Productivity	Could you estimate how your entire office building have affected your productivity at work?	4.50	1.20	5.10	1.21	0.60	0.04	0.50

Table 1. Comparison (dependent t-test results) between mean differences in timber-rich and non-timber workplaces.

size (Cohen's D = 0.86). This suggests a more favourable perception of sun glare in timber-rich environments. Satisfaction with daylight was also notably higher in timber-rich offices (Mean = 5.00, SD = 1.26) compared to non-timber offices (Mean = 3.77, SD = 1.36) with a significant mean difference of 1.23 ($p = 0.02$). The effect size (Cohen's D = 0.95) indicates a large and meaningful difference in daylight satisfaction, further supporting the positive impact of timber-rich environments on this aspect. In terms of acoustic satisfaction, participants in timber-rich offices reported significantly higher satisfaction with acoustics (Mean = 5.35, SD = 1.31) compared to those in non-timber offices (Mean = 3.60, SD = 1.73), with a substantial mean difference of 1.75. This difference was statistically significant ($p = 0.00$), and the effect size (Cohen's D = 1.14) suggests a large effect, which indicates a better acoustic environment in timber-rich offices. The participant reported improved acoustic environment in this timber-rich office may be attributed to the use of timber for structural elements like columns and beams that might have helped with sound absorption and reduce noise levels. Also, the larger windows in this office likely contributed to a quieter environment by allowing more natural light and enhancing the overall feeling of openness, further improving acoustic comfort. The reduction in concrete and the focus on mass timber construction in this timber-rich office also has helped minimise vibrations to contribute to the positive acoustic experience reported by participants.

Participants in timber-rich offices rated their overall comfort significantly higher (Mean = 6.20, SD = 0.77) compared to those in non-timber offices (Mean = 5.61, SD = 1.05), with a mean difference of 0.59 ($p = 0.00$). The effect size (Cohen's D = 0.84) reflects a large and significant difference, indicating that employees in timber-rich offices perceive their workplace as more comfortable overall. For the factors that showed no significant differences, such as building image, air quality, air smell, overall lighting, noise levels (both outside and inside), and décor layout, it is possible that the lack of statistical significance may be attributed to the relatively low number of participants in this study. A larger sample size might help to better capture the subtle differences between office settings and provide more robust findings. Therefore, to clarify the differences between the office settings, future research with a much larger number of participants is recommended to increase the statistical power and ensure that these results are more generalisable.

Overall participants in timber-rich workplaces reported more favourable perceptions in several key areas, including temperature satisfaction, glare from the sun, daylight, health, and overall comfort. Suggesting that timber-rich environments may have a positive impact on employee well-being and satisfaction.

When it comes to health perceptions, employees in timber-rich offices reported feeling significantly healthier (Mean = 5.05, SD = 0.97) compared to those in non-timber offices (Mean = 4.48, SD = 1.27) that had a mean difference of 0.57. This difference was statistically significant ($p = 0.01$) and the effect size (Cohen's D = 0.82) suggests a moderate to large effect. This highlights that the timber-rich office environment may contribute to a greater sense of health and well-being among employees.

Variable	Non-timber		Min	Max	Timber-rich		Min	Max
	Mean	Std. Dev			Mean	Std. Dev		
At my work, I feel bursting with energy	3.55	1.03	1	5	3.75	1.12	2	5
I find the work that I do full of meaning and purpose	4.19	1.38	1	6	3.85	1.39	1	6
Time flies when I am working	4.58	1.09	2	6	4.40	1.14	2	6
At my job, I feel strong and vigorous	3.71	1.37	1	6	3.85	1.31	2	6
I am enthusiastic about my job	4.55	1.06	2	6	4.00	1.30	1	6
When I'm working, I forget everything else around me	3.58	1.29	0	6	3.55	1.10	1	5
My job inspires me	3.61	1.33	1	6	3.55	1.47	1	6
When I get up in the morning, I feel like going to work	3.84	1.42	1	6	3.65	1.66	0	6
I feel happy when I am working intensely	4.29	1.01	2	6	4.35	0.93	3	6

Table 2. Descriptive statistics of work engagement variables (positive aspects).

Variable	Non-timber		Min	Max	Timber-rich		Min	Max
	Mean	Std. Dev			Mean	Std. Dev		
I am proud of the work that I do	1.39	1.26	0	4	1.70	1.17	0	4
I am immersed in my work	1.48	1.12	0	4	1.95	0.99	0	4
I can continue working for very long periods at a time	1.87	1.10	0	4	1.95	1.23	0	4
To me, my job is challenging	1.45	0.99	0	4	1.65	0.88	0	3
I get carried away when I'm working	2.23	1.15	0	4	2.20	1.06	1	4
At my job, I am very resilient, mentally	1.55	1.06	0	4	1.30	0.98	0	3
It is difficult to detach myself from my job	2.00	1.32	0	4	2.05	1.19	0	4

Table 3. Descriptive statistics of work engagement variables (negative aspects).

In terms of productivity, participants working in timber-rich offices reported significantly higher productivity ratings (Mean = 5.10, SD = 1.21) compared to those in non-timber offices (Mean = 4.50, SD = 1.20) showing a mean difference of 0.60. This difference was statistically significant ($p = 0.04$), and the effect size (Cohen's D = 0.50) indicates a moderate effect. This suggests that the timber-rich office environment may contribute to higher productivity perceptions among employees.

Negative and positive aspects of work engagement

The results reveal generally high levels of work engagement across both timber-rich and non-timber environments, with some variations between the two groups. As shown in Table 2, respondents in both settings reported relatively strong levels of energy, enthusiasm, and immersion in their work.

On average, participants in non-timber environments reported feeling slightly less engaged than those in timber-rich environments across some indicators. For instance, those in timber-rich settings reported slightly higher mean scores in feeling bursting with energy (Mean = 3.75 vs. 3.55), strong and vigorous (Mean = 3.85 vs. 3.71), and happy when working intensely (Mean = 4.35 vs. 4.29).

Notably, employees in non-timber settings rated "the work that I do is full of meaning and purpose" slightly higher (Mean = 4.19) compared to those in timber-rich settings (Mean = 3.85), suggesting a stronger sense of purpose in that group. Both groups indicated that "time flies when working" (Mean = 4.58 for non-timber, 4.40 for timber-rich) which reflected high levels of immersion in tasks.

Feelings of enthusiasm were slightly higher in the non-timber group (Mean = 4.55 vs. 4.00), while both groups reported similar scores for statements such as "I forget everything else around me when working" and "My job inspires me," with only minor variations. The results suggest that while both environments support positive work engagement, timber-rich spaces may offer a slight advantage in promoting physical energy and emotional intensity.

While there are positive indicators, the results also suggest areas of concern regarding work engagement and overall well-being (Table 3). Participants from both groups reported lower levels of pride and mental resilience in their work. In particular, the timber-rich group indicated slightly higher pride in their work (Mean = 1.70) compared to the non-timber group (Mean = 1.39), but overall values suggest limited personal fulfilment. Similarly, self-reported mental resilience was low in both groups, with non-timber respondents averaging 1.55 and timber-rich respondents even lower at 1.30, highlighting potential struggles with stress or coping under pressure.

In terms of immersion, the timber-rich group reported higher levels of work immersion (Mean = 1.95) compared to non-timber respondents (Mean = 1.48), which may reflect greater task engagement, though it could also indicate difficulty in detaching from work. This is supported by the item "It is difficult to detach myself from my job," where both groups scored similarly (around 2.00), suggesting challenges with maintaining work-life boundaries.

Participants in both groups also rated the challenge level of their jobs relatively low, with means of 1.45 (non-timber) and 1.65 (timber-rich), possibly indicating a lack of stimulating or demanding tasks. While the item "I get carried away when I'm working" had slightly higher mean scores (around 2.20) in both groups, the overall picture reflects moderate engagement with notable gaps in inspiration, pride, and resilience.

These findings underscore the importance of behavioural research addressing psychosocial factors, workplace support, and job design to improve well-being and engagement across different environments.

Cortisol results
For our total sample of cortisol tested participants our study collected n = 51 samples, with n = 27 participants in the first round and n = 24 participants in the 2nd round. Due to inconclusive results or participant non-appearance, we were left with n = 23 matched participant samples from both rounds. Analysis of these data showed that average cortisol results fell between Stage 1 (Mean = 317.200 pg/mg or log(5.33)) to Stage 2 (Mean = 286.421 pg/mg or log(5.23)), that is, on average, office workers had lower cortisol (lower stress levels) after moving into the timber workplaces. Although statistical analysis using both t-test and ranksum tests show no statistically significant differences.

Multivariate regression results
Our regression analysis is provided only as part of the pilot's methodological design, and to inform direction of future research. The studies small sample size (n = 44) relative to the number of variables of interest generates issues of over-specification, inflated standard errors and low statistical power. We do however provide multiple specification in Tables 4, 5 and 6 with smaller numbers of predictors, selecting first only demographic characteristics (1), then only self-reported measures (2), before finally the complete specification with all predictors of interest included (3).

Independent variables	(1) Productivity: Environmental Conditions	(2) Productivity: Environmental Conditions	(3) Productivity: Environmental Conditions
Timber dummy	0.368 (0.389)		− 0.300 (0.591)
Cortisol level	0.000 (0.001)		0.000 (0.001)
Age	0.016 (0.024)		− 0.042 (0.032)
Male dummy	0.093* (0.404)		0.494 (0.462)
Single dummy	− 0.407 (0.580)		− 0.743 (0.559)
Annual Income	− 0.098 (0.059)		0.004 (0.071)
Postgraduate dummy	0.249 (0.525)		− 0.298 (0.658)
Building Image Rating		0.092 (0.211)	− 0.006 (0.319)
Interior Aesthetic Rating		− 0.013 (0.147)	0.023 (0.198)
Rating Overall Comfort		0.049 (0.211)	0.089 (0.356)
Feeling Healthy-Building		0.567*** (0.149)	0.538** (0.179)
Life Satisfaction		− 0.113 (0.218)	− 0.256 (0.262)
Perceived Overall Health		0.106 (0.224)	0.017 (0.314)
Feelings on Company		− 0.036 (0.112)	− 0.082 (0.147)
Work & Well-being Survey		− 0.007 (0.267)	0.137 (0.354)
CASBEE-Office Health		0.788 (0.544)	1.323 (1.036)
Constant	3.107 (0.896)	− 84.46 (1.097)	57.10 (1.292)
N	44	51	44
R-squared	0.203	0.472	0.521
Prob > F	0.068	0.000	0.000

Table 4. Factors impacting office worker Productivity: Environmental Conditions. Ordinary Least Squares (OLS) regression (dependent variable) coefficient. Standard errors (robust) in parentheses. $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Independent variables	(1) Productivity: Entire Office Building	(2) Productivity: Entire Office Building	(3) Productivity: Entire Office Building
Timber dummy	0.519† (0.291)		0.459 (0.362)
Cortisol level	0.000 (0.000)		0.001 (0.000)
Age	0.032		−0.006 (0.029)
Male dummy	0.646† (0.345)		0.238 (0.315)
Single dummy	−0.353 (0.493)		−0.451 (0.516)
Annual Income	−0.130* (0.054)		−0.053 (0.060)
Postgraduate dummy	0.347 (0.403)		−0.166 (0.520)
Building Image Rating		0.227 (0.144)	0.340 (0.229)
Interior Aesthetic Rating		−0.135 (0.127)	−0.153 (0.163)
Rating Overall Comfort		−0.025 (0.198)	−0.228 (0.309)
Feeling Healthy-Building		0.380** (0.132)	0.230 (0.160)
Life Satisfaction		−0.043 (0.150)	0.143 (0.213)
Perceived Overall Health		−0.118 (0.191)	−0.422 (0.256)
Feelings on Company		−0.003 (0.094)	−0.008 (0.098)
Work & Well-being Survey		0.077 (0.235)	0.286 (0.270)
CASBEE-Office Health		1.274** (0.459)	1.216† (0.705)
Constant	309.8*** (0.789)	−71.26 (1.128)	13.31 (1.350)
N	44	51	44
R-squared	0.257	0.566	0.630
Prob > F	0.047	0.000	0.000

Table 5. Factors impacting office worker Productivity: Entire Office Building. Ordinary Least Squares (OLS) regression (dependent variable) coefficient. Standard errors (robust) in parentheses. $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

In Table 4: Productivity: Environmental Conditions, specification 1 we see males (compared to females) report higher productivity relating to the environmental conditions. We also see that for our independent variable of Feeling Healthy-Building in both specification 2 and 3 is a statistically significant positive result at a $p < 0.001$ and $p < 0.01$ level, indicating that greater feelings of health in the building may be associated with higher productivity in environmental conditions.

For Table 5: Productivity: Entire Office Building, we see that for our specification 2 Feeling Health-Building and specification 3 IV CASBEE-Office Health, are both statistically positive result at a $p < 0.05$ level, suggesting that improvements in office health, as measured by both, may be associated with higher productivity in the entire office.

Lastly, regarding Table 6: Productivity Work Engagement and Performance, we only see a statistically significant result for specification 2 Work & Wellbeing Survey responses being positively associated with work engagement and performance ($p < 0.05$).

Naturally, such results warrant further exploration to better understand the underlying dynamics. But as previously stated, this not currently possible due to insufficient sample size.

Discussion

Research has shown that biophilic design elements, such as timber-rich environments, can have a positive impact on various occupant outcomes, including stress responses, comfort, and cognitive activity. Specifically, the presence of timber has been shown to elicit positive physiological responses, attitudes and moods in building occupants due to its tonal, tactile, and olfactory qualities[38]. Given the significant amount of time individuals spend in office environments, investigating these factors is crucial to ensuring that future workplace design is guided by contemporary evidence, enabling tangible improvements in occupant outcomes. In this observational

Independent variables	(1) Work Engagement and Performance	(2) Work Engagement and Performance	(3) Work Engagement and Performance
Timber dummy	−0.118 (0.107)		−0.0134 (0.155)
Cortisol level	0.000 (0.000)		0.000 (0.000)
Age	0.002 (0.008)		0.010 (0.009)
Male dummy	0.018 (0.124)		0.076 (0.115)
Single dummy	−0.074 (0.171)		0.000 (0.205)
Annual Income	0.006 (0.019)		−0.017 (0.022)
Postgraduate dummy	0.289† (0.153)		0.329† (0.180)
Building Image Rating		0.143† (0.076)	0.202 (0.123)
Interior Aesthetic Rating		0.043 (0.042)	0.055 (0.062)
Rating Overall Comfort		−0.138† (0.081)	−0.197 (0.122)
Feeling Healthy-Building		−0.075 (0.061)	−0.109† (0.060)
Life Satisfaction		0.104 (0.063)	0.139† (0.069)
Perceived Overall Health		−0.158† (0.087)	−0.153 (0.104)
Feelings on Company		−0.014 (0.042)	−0.020 (0.049)
Work & Well-being Survey		0.245* (0.101)	0.175 (0.103)
CASBEE-Office Health		−0.099 (0.170)	−0.150 (0.275)
Constant	274.8*** (0.362)	219.7*** (0.447)	207.9*** (0.570)
N	44	51	44
R-squared	0.174	0.307	0.393
Prob > F	0.015	0.044	0.063

Table 6. Factors impacting office worker Productivity: Work Engagement and Performance. Ordinary Least Squares (OLS) regression (dependent variable) coefficient. Standard errors (robust) in parentheses. $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

field study, we found mixed associations between occupancy of a timber-rich workspace and self-reported comfort, wellbeing, and productivity; several outcomes were not statistically significant.

Pilot studies such as this one, conducted in the actual field (i.e. office workspace) may provide quantification of the potential benefits of incorporating natural elements in office design to enhance employee wellbeing and productivity. While noise in field-based experiments and real-world settings is less controlled or manageable in laboratory settings, there is considerable scientific value in approaches “grounded in realistic representations of indoor environments rather than assumptions”, pg. 10[39]. Evaluating the impact of timber on occupant wellbeing, comfort and productivity in an environment that deals with the contextual complexity of real-world settings—as this study has done—offers insights that are potentially more applicable and informative than those experiments held in the artificial constraints of a laboratory context.

Respondent perceptions attained via the self-reported questionnaire supported the idea that timber-rich workplaces contribute to improved comfort, productivity and wellbeing compared to non-timber settings. For the participants situated in the timber environment, they reported positive impacts to their perceived health, and perceived IEQ parameters were reported. For instance, one specific factor that had a notable positive relationship was acoustics in the timber-rich environment, compared to the concrete setting. This may be attributed to the different sound absorption qualities between timber and concrete wall materials. In terms of health and productivity, participants in the timber-rich office also reported higher levels of perceived health and productivity. Suggesting that the timber-rich environment may foster improved well-being and work performance. This aligns with Shen et al.’s 2020[40] findings on timber-rich rooms, cognitive performance and work-environment satisfaction, and is consistent with principles of ART, which links nature exposure to improved psychological and physiological recovery.

It is important to note that cortisol measurements in this study were on average lower in office workers in timber settings, our t-test analysis showed no statistically significant differences., The novel approach of measuring cortisol by hair samples in the field has several limitations, which will require future research to employ improved methods and increased protocols to ensure sufficient data collection adequate for greater statistical power in analysis. The sample size (n = 24), while one of the largest samples ever collected for this type of timber-rich office space research, is insufficient for meaningful statistical and econometric (multivariate) analysis. Collecting hair cortisol outside of the laboratory setting also created issues relating to intra-individual variability and/or cofounding factors such as medication, sleep, diet, and other stressors, again all issues for consideration in future research.

Our self-reported descriptive measures indicate that timber-rich interiors can be a positive addition to occupant perceptions of comfort, well-being, and productivity. This suggests that organisations and developers should consider integrating more biophilic elements, especially timber in workplace design. These interventions could play a critical role in encouraging employees to return to the office[9,11,40,41], a matter of world-wide interest in developed economies since the COVID-19 pandemic. Organisations may also seek workplaces with strong BD credentials to support employee health and productivity. Our study demonstrates that timber-rich environments may be a positive contributor to such credentials. Given the significant economic impact of absenteeism and reduced employee performance, this study suggests that the integration of timber—even in simple fit-out scenarios—can represent a low-cost, low-risk strategy for organisations to improve productivity and related workplace outcomes.

The implications of this research to various stakeholders are multifaceted, with relevance to design practice, workplace valuation, and theoretical investigations into BD. Contemporary discourse surrounding architectural and interior design practice, particularly as it relates to materiality, are largely focused on the goal of decarbonising the built environment. While this issue is important, it is equally critical to ensure that designed and constructed spaces also consider the human-centred dimensions of building materiality. This studies methodology provides a vovel mixed method approach to exploration of timber-rich environments significance in influencing key human-centred metrics such as productivity, health and comfort. It also provides a unique opportunity to explore the economic and financial benefits for developers and lease holders. Previous research has shown that workplaces with BD features such as natural daylight[42] and views of greenery[43] tend to command a value premium over those that do not. Thus, similar financial premiums may be achieved by developers who integrate timber into fit-out and design. This prompts the question of whether the human-centred value of biophilic elements is adequately reflected in the commercial valuation of such spaces. Considering recent increases in vacancy rates across major commercial real estate markets such as Tokyo, New York and London[44] exploring the potential for timber-rich environments to enhance financial returns for developers and asset holders presents a promising area for further economic research.

Conclusion

This first-of-its-kind pilot study aimed to contribute to BD research through the collection and analysis of quantitative data relating to office worker health and productivity. Specifically, this study involved the scientific exploration of the viability of timber-rich office environments as a means to positively influence occupant health and productivity. While our studies results are not generalizable, our pilot does provide a first of its kind experimental field-based methodology for quantification of timber-rich environments influence on self-reported and biological measures of occupant health and productivity. In practice, statistically significant analysis and results relating to the cortisol measurement and our multivariate regression analysis were not possible, primarily due to both the small size of the study sample population. This primary issue stems from the shortage of these kinds of timber-rich environments in the Australian office building and construction sector. As timber rich office environments grow in popularity across Australia and the world, this methodology provides future commercial and academic research opportunities using this unique mixed method of quantitative measures and biomarkers to better understand the scope of impacts that biophilic elements, such as timber-rich environments, can have on workplace occupant wellness and productivity.

Data availability

Data are available upon request from the lead author Dr Stephen Whyte [sg.whyte@qut.edu.au] (mailto:sg.whyte@qut.edu.au) in conjunction with written approval of the Building4.0 CRC and Sumitomo Forestry Australia.

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Author contributions

SW led the project. SW: Conceptualization, Methodology, Data Collection, Data Curation, Formal Analysis, Writing—Original Draft, Supervision, Project Administration. KS: Formal Analysis, Writing—Original Draft. CC: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing—Original Draft, Supervision. YZ: Formal Analysis, Writing—Original Draft. DF: Conceptualization, Methodology, Data Collection, Data Curation, Formal Analysis, Writing—Original Draft. SF: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing—Original Draft. HFC: Conceptualization, Methodology, Writing—Original Draft. RK: Conceptualization, Methodology, Resources, Writing—Original Draft. KJM: Formal Analysis, Writing—Original Draft. MRV: Formal Analysis, Writing—Original Draft. ZS: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing—Original Draft.

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Declarations

Competing interests

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Research ethics and informed consent

This study and all data collection (i.e. both survey and hair cortisol) was conducted in accordance with the projects 2023 Queensland University of Technology Human Research Ethics Committee Approval—no. #6765. All study subjects provided written informed consent prior to participation.

Additional information

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