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Impact of WELL certification on occupant satisfaction and perceived health, well-being, and productivity: A multi-office pre- versus post-occupancy evaluation

Nasim Ildiri [a], Heather Bazille [b,c], Yingli Lou [a], Kathryn Hinkelman [d], Whitney A. Gray [c], Wangda Zuo [d,e,*]

[a] Department of Civil, Environmental and Architectural Engineering, University of Colorado Boulder, Boulder, CO, 80309, USA
[b] Department of Design and Environmental Analysis, Cornell University, Ithaca, NY, 14853, USA
[c] International WELL Building Institute, New York, NY, 10001, USA
[d] Department of Architectural Engineering, Pennsylvania State University, University Park, PA, 16802, USA
[e] National Renewable Energy Laboratory, Golden, CO, 80401, USA

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ABSTRACT

The WELL Building Standard (WELL) is currently one of the most comprehensive building certification programs that aim to enhance the health and well-being of building occupants. However, there is a lack of systematic evaluation of the effectiveness of WELL in achieving its goal. This study investigates the impact of WELL certification on occupant satisfaction with the workplace and occupant perceived health, well-being, and productivity. More than 1300 pre- and post-occupancy survey responses provided by the nearly same cohort of occupants from six companies in North America were quantitatively analyzed. The results showed that transitioning to WELL certified offices from non-WELL certified offices had a positive impact on occupant satisfaction with the workplace and occupant perceived health, well-being, and productivity, with increases in means from pre-to post-occupancy being highly statistically significant. The majority of the studied occupant satisfaction parameters as well as occupant perceived mental health had large effect sizes. While they improved from pre-to post-occupancy, the analysis revealed small effect sizes for occupant perceived physical health and self-assessed productivity. The majority of the effect sizes for the perceived well-being parameters were large and medium. In addition to analyzing the survey responses in aggregate, the responses were examined at the individual company level to confirm the by-company and aggregate findings aligned.

1. Introduction

With people spending approximately 90% of their time indoors [1], buildings can significantly influence quality of life. There are many design and operational factors that affect how a building meets occupants' needs. Mujan et al. [2] identified thermal comfort, indoor air quality, visual comfort, and acoustic comfort as the four primary indoor environmental quality (IEQ) factors that influence occupant comfort in indoor built environments and strongly linked these factors with occupant health and productivity. Geng et al. [3] carried out an experimental study on a group of participants to measure the effects of thermal comfort on occupants' productivity and found that increased thermal satisfaction resulted in higher productivity. In an experiment conducted by Allen et al. [4] on the effects of IEQ on occupants' cognitive function scores, occupants under green building conditions reported higher scores when compared with occupants under conventional building conditions. Sundstrom et al. [5] conducted a field study on the effects of office noise on occupants and reported that disturbance by noise negatively impacted satisfaction with the job and environment. Figueiro and Rea [6] found that calibrated light exposures have an impact on sleep quality and mood of the individuals working in a building. It is known that factors other than the traditionally studied IEQ parameters can also affect occupant satisfaction and perceived health, well-being, and productivity [7]. Schiavon and Altomonte [8] found that factors such as an office's spatial layout and distance from a window have statistically significant influences on occupant satisfaction. Yin et al. [9] examined

* Corresponding author. Department of Architectural Engineering, Pennsylvania State University, University Park, PA, 16802, USA.
E-mail address: wangda.zuo@psu.edu (W. Zuo).

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the psychological and cognitive responses to biophilic design elements in an office building and found that exposure to natural elements in the indoor environment resulted in decreased negative emotions and blood pressure, improved short-term memory, and increased positive emotions. In another study conducted by Grimani et al. [10], workplace nutrition and physical activity interventions improved occupant productivity and work performance. Puleio and Zhao [11] reported that interventions that promote occupant health and wellness at work can increase physical well-being and eventually result in higher levels of job satisfaction.

1.1. WELL building standard

Over the years, several tools have been developed to enhance the dynamics between buildings, occupants, and the environment such as *Leadership in Energy and Environmental Design* (LEED) by U.S. Green Building Council [12], *Building Research Establishment Environmental Assessment Method* (BREEAM) by Building Research Establishment [13], *WELL Building Standard* (WELL) administered by the International WELL Building Institute (IWBI) [14], *Fitwel* from the Center for Active Design [15], and the *Living Building Challenge* by the International Living Future Institute [16]. Among these, WELL is one of the most comprehensive and fastest growing standards that focuses primarily on the health and well-being of building occupants [17]. Since the launch of WELL in 2014, more than 72 million square-feet of commercial and residential space around the world have been WELL certified [18].

WELL was pioneered by Delos Living LLC [19] and continues to be developed and is administered by the International WELL Building Institute pbc (IWBI) [20]. WELL certification made its debut with the launch of the first version of WELL (WELL v1) [21] in 2014. IWBI released the second version of the standard (WELL v2) [22] in 2020, adapting its requirements with the evolving state-of-art research in human health and building design. Spaces of any size, ranging from an interior space to an entire building or campus of buildings, that meet WELL requirements can become WELL certified [23]. The emphasis of WELL v1 was on commercial and institutional buildings, consisting of New and Existing Buildings, New and Existing Interiors, and Core and Shell projects. WELL v2 can be applied by spaces with more diverse applications, including multi-family residentials, and has a single rating system for all project types.

WELL consists of over a hundred features, evidence-based health and well-being strategies that can be implemented during the design and operational phases of buildings [14]. While some WELL features are comparable with requirements in green building standards, others target corporate policies and cultures within organizations. WELL v1 features fall within seven WELL concepts: Air, Water, Nourishment, Light, Fitness, Comfort, and Mind. Whereas, WELL v2 features are organized under ten concepts. Examples of WELL features include strategies to enhance indoor air quality, improve water quality and promote hydration, encourage healthy eating habits, control exposure to light to minimize disruption to the human circadian system, implement active design elements throughout the building to encourage fitness regiments, and create spaces that support a diverse set of personal and work-related tasks [21]. There are also multiple WELL features that specifically aim to promote mental and emotional well-being through design interventions (e.g., biophilic design elements), supportive programs (e.g., stress management workshops), and policies (e.g., employer-based health insurance). WELL is compatible with leading global green building standards (e.g., LEED, BREEAM, Green Star).

To receive certification, WELL features are required to be third-party verified through documentation and onsite testing of space performance parameters [24]. WELL features are either preconditions, required to achieve any level of WELL certification, or optimizations, optional enhancements to achieve higher certification levels. Under WELL v1, spaces can be awarded WELL certification according to the following scale: Silver (meeting all applicable preconditions), Gold (meeting all applicable preconditions and 40% of applicable optimizations) or Platinum (meeting all applicable preconditions and 80% of applicable optimizations). WELL v2 uses a point system, and it also offers an additional level of certification: Bronze. This study tracked companies that transitioned into WELL v1 certified offices. Therefore, the focus of the study is on WELL v1 accordingly.

1.2. Post-occupancy evaluation surveys

WELL v1 Feature 86 requires all New and Existing Buildings and Interiors projects with 10 or more occupants administer a post-occupancy evaluation survey annually [25]. The survey must be completed by a representative sample of at least 30% of the occupants. The survey must assess, at minimum, the occupants' perception of the building's or space's acoustics, air quality, cleanliness, furnishings, layout, lighting, maintenance, and thermal comfort. It is recommended the survey be administered by a third-party survey provider to ensure credibility and objectivity of the results.

Post-occupancy evaluation surveys are used to systematically gather feedback from occupants to better understand how successfully a building or space has achieved its design goals. Post-occupancy evaluation surveys can provide actionable insights that can be used to help address the gaps between the design intentions and the actual outcomes of a project. Results of post-occupancy evaluation surveys can also be used as evidence to inform future design projects and improve standards, like WELL. Post-occupancy evaluation surveys should be conducted at least six months after occupancy to ensure occupants have had time to adjust to the new building or space [26]. If possible, it is best to conduct both a pre-occupancy evaluation survey and a post-occupancy evaluation survey because the results of a pre-occupancy evaluation survey can be used as baseline data to compare the post-occupancy data [27].

1.3. Impact of WELL-certified offices

Despite post-occupancy evaluation surveys being a requirement of WELL certification [25,28], only a few studies that have investigated the effectiveness of WELL in achieving its goals have been published to date. Candido et al. [29] compared the post-occupancy occupant satisfaction, perceived productivity and health within WELL certified and non-WELL certified Australian offices and reported higher scores for overall satisfaction, workability, perceived productivity and health for WELL certified office occupants. Licina and Yildirim [30] compared pre- and post-occupancy survey responses of the same cohort of occupants and studied satisfaction with IEQ, sick building syndrome (SBS) symptoms, and self-reported productivity before and after relocating to WELL certified office buildings in Europe. They found statistically significant positive changes in occupant overall satisfaction with building and workplace for two out of the three studied buildings. They also reported insignificant differences between pre- and post-occupancy productivity and SBS symptoms, except for tiredness. In another study, Licina and Langer [31] measured and quantitatively compared indoor air quality (IAQ) parameters of two office buildings in Europe before and after relocation to WELL certified office buildings and found that satisfaction with IAQ increased despite objectively measured IAQ parameters in non-WELL certified and WELL certified buildings not being significantly different.

1.4. Contribution and research questions

While the above research investigated the impact of WELL strategies on occupants, the focus was primarily on occupant satisfaction with environmental factors and less attention was given to topics related to health and well-being of occupants. While environmental factors are important, detailed study of occupant perceived health and well-being are critical to include when assessing the effectiveness of

implementing WELL strategies. Further, past studies covered only a limited sample of WELL certified buildings and spaces and only two of the studies included both pre- and post-occupancy data. To fill these gaps, this study comprehensively analyzed the impacts of WELL certification on occupants from four perspectives: satisfaction with the workplace and perceived health (physical and mental), well-being, and productivity. To the authors' best knowledge, this study is the largest and one of the most comprehensive pre- versus post-occupancy analyses of the effect that WELL certification has on building occupants. Nearly the same cohort of more than 1300 occupants from six different companies in North America participated in this longitudinal study. The analyzed occupant satisfaction and perceived well-being data covers a wide range of parameters, well beyond the conventional IEQ-related factors. Unlike the prior research mentioned, the questions used in this study to measure occupant perceived health were drawn from a psychometrically validated questionnaire, which is of critical importance when measuring perceived mental and physical health. Having a large sample size and the results of a pre-occupancy evaluation survey that can be used as baseline data to compare with the post-occupancy data provides additional validity and strength to this analysis.

This pre- versus post-occupancy evaluation investigates the impact of WELL certification on occupant satisfaction with the workplace and occupant perceived health, well-being, and productivity using a larger sample than previous research. It also builds on the currently limited existing research that looks at the impact of WELL strategies on occupants by providing a more holistic view of the impact that WELL certification can have on human health and well-being. Occupant satisfaction with the workplace and occupant perceived health, well-being, and productivity were studied over time as six companies transitioned from offices that were not WELL-certified to offices that were. The pre-post study addresses four primary research questions:

1. Are there significant differences in occupant satisfaction with the workplace between the WELL-certified offices and the not WELL-certified offices?
2. Are there significant differences in occupant perceived health between the WELL-certified offices and the not WELL-certified offices?
3. Are there significant differences in occupant perceived well-being between the WELL-certified offices and the not WELL-certified offices?
4. Are there significant differences in occupant perceived productivity between the WELL-certified offices and the not WELL-certified offices?

Based on the intention of the WELL Building Standard, the hypotheses of this study are that occupant satisfaction with the workplace and perceived productivity are significantly higher and occupant perceived health and well-being are significantly better for the WELL-certified offices compared with their pre-occupancy baseline measurements.

2. Methodology

2.1. Selection and description of companies

Between 2015 and 2018, Delos offered a free post-occupancy evaluation survey program to all companies who registered for WELL v1 certification and were required to administer an annual post-occupancy evaluation survey to earn the certification. To participate in the program, companies agreed to administer the Delos Building Wellness Survey both before (pre-occupancy) and after (post-occupancy) they transitioned into their WELL certified offices. The companies also agreed to aim for a 50% response rate to both the pre- and post-occupancy surveys, instead of 30% required to achieve Feature 86. Seven companies in the program were selected to be part of this study based on the following criteria: completion of both a pre-occupancy and a post-occupancy Building Wellness Survey and achievement of WELL v1 certification. The survey respondent samples from the seven companies were evaluated for representativeness using a chi-square test. One company was eliminated from the study because its survey respondent sample was determined to be unrepresentative. The sample consisted of a disproportionate number of females in a similar position in the company.

Of the six companies included in the study, all six were located in North America. Five of the companies were located in the United States and one in Canada. The five companies in the United States relocated to different offices in which they renovated and the one in Canada renovated their existing office. All six of the renovated offices achieved WELL v1 certification for New and Existing Interiors. Two of offices achieved WELL v1 Silver, two achieved WELL v1 Gold, and two achieved WELL v1 Platinum. The companies began occupying their WELL certified offices between September 2015 and September 2017. The companies' offices ranged in size from 29 (company A) to 484 (company D) occupants. The characteristics of the six companies' offices are summarized in Table 1. The companies' achieved WELL features (both preconditions and optimizations) and onsite WELL performance verification measurements (those required by preconditions only) determined to be directly relevant to the satisfaction parameters studied can be found in Tables A.2 and A.3, respectively, in the Appendix.

2.2. Survey protocol

The Building Wellness Survey [32] was administered by Delos Living LLC [19] online to all six companies both pre- and post-occupancy to study the impact of the transition to WELL certified offices on occupant satisfaction and perceived health, well-being, and productivity. A web link to the survey was emailed to all employees who regularly occupied each of the offices. The email was sent by an employee in the office who was well-known and respected to encourage participation. The employees' participation in the survey was completely voluntary, and they were not compensated for completing it. At the beginning of the survey, participants were informed their responses would be kept completely confidential from their employer and results would only be presented in aggregate. The survey was estimated to take 10–15 minutes to complete and could be completed via a computer or any mobile device using Apple iOS, Android, or Blackberry software. During the survey period, participants could begin the survey and return to it if they needed to pause and leave it at any time. At the end of the survey, they were asked to voluntarily provide their work email address, so their survey responses could be tracked over the course of the study. Participants were assured that if they provided their email address, it would not be shared with their employer. The survey was kept open two to four weeks to target the 50% participation rate. Delos sent emails weekly to the employees in the offices who sent the survey reminding them to follow up with the employees in their offices to encourage them to complete the survey. Pre-occupancy surveys were conducted prior to the offices transitioning to their new WELL-certified offices. Post-occupancy surveys were conducted 6–13 months after the companies occupied their new offices.

Table 1
Characteristics of the six companies' offices.

	Company					
	A	B	C	D	E	F
Location (country)	USA	USA	USA	USA	USA	CA
Number of occupants						
Pre-Occupancy	40	29	78	358	318	267
Post-Occupancy	40	29	78	484	350	267
WELL certification						
Pre-Occupancy	N/A	N/A	N/A	N/A	N/A	N/A
Post-Occupancy	Gold	Platinum	Platinum	Silver	Silver	Gold

2.3. Building Wellness Survey

The Building Wellness Survey [32] was developed by Delos Living LLC to capture occupant satisfaction and perceived health, well-being, and productivity. The first section collects occupants' demographic information, including gender, age, hours worked weekly in the office, and length of employment. The second section captures occupants' degree of satisfaction with workplace parameters that are targeted by WELL (e.g., indoor air quality, lighting, and wellness programs). Level of satisfaction is assessed using a 7-point Likert scale [33], from very satisfied (+3) to very dissatisfied (−3) with a neutral midpoint (0). Table A.1 in the Appendix lists the Building Wellness Survey items used in this study to measure occupant satisfaction with the workplace. The third section of the Building Wellness Survey is comprised of the eleven absenteeism and presenteeism questions of the World Health Organization's Health and Work Performance Questionnaire (HPQ) [34,35], a practical and psychometrically validated survey that has been widely utilized for measuring work productivity in a variety of workplace settings [36,37]. For this study, occupants' perceived productivity was measured using absolute presenteeism scores, calculated using one HPQ presenteeism question: *How would you rate your overall job performance on the days you worked during the past 4 weeks (28 days)?* Absolute presenteeism is defined as "a measure of actual performance in relation to possible performance" [38]. The absolute presenteeism scores range from 0, indicating "total lack of performance during time on the job" to 100, representing "no lack of performance during time on the job" with higher scores suggesting a "lower amount of lost performance" [35]. In the fourth section of the Building Wellness Survey, occupants are asked to report their level of agreement with statements related to their workplace well-being (Table A.1), including workplace pride, motivation, employer support, health and wellness culture, and workstyle accommodation [32,39]. Level of agreement is evaluated using a 5-point Likert scale, from strongly agree (+2) to strongly disagree (−2) with a neutral midpoint (0). The last section of the Building Wellness Survey is comprised of all of the questions from the Medical Outcome Study 12-Item Short-Form Health Survey (SF-12v2) [40]. The psychometrically validated SF-12v2 is one of the most commonly used tools to measure general health status [41]. With the SF-12v2 questions, mental and physical health scores can be calculated using the mental component summary (MCS) and physical component summary (PCS) regression coefficients [42], ranging from 0 to 100 (higher scores indicating better health status). MCS and PCS scores were calculated for this study using the SF-12v2 questions and PRO CoRE, a software licensed by QualityMetric, the copyright owner of the SF-12v2 [43].

2.4. Data analysis and statistical methods

To address the research questions, the survey dataset was analyzed in two major steps. First, the aggregate pre- and post-occupancy survey data from the six companies were studied using descriptive and inferential statistical analyses to examine how occupant satisfaction and perceptions changed from pre- to post-occupancy. Second, the same pre-post dataset was examined by company using descriptive statistics to confirm the by-company findings aligned with the findings of the descriptive analysis of the aggregate sample. Statistical analyses were carried out with R programming language [44], and visual presentations were generated using Origin software [45]. The pre-post dataset was not examined by-company using inferential statistics because the companies' sample sizes were uneven and some of the companies had relatively small sample sizes. The companies' post-occupancy occupant satisfaction means were compared with their relevant achieved WELL features and onsite WELL performance verification measurements to try to explain any differences in the satisfaction results across companies.

Aggregate data were studied through a careful set of descriptive and inferential statistical analyses. Descriptive statistical results have been reported in the form of means, standard deviation (SD) and the 25th and 75th percentiles pre- and post-occupancy. Mean differences were calculated by subtracting pre-occupancy means from post-occupancy means ($\Delta\text{Mean} = \text{Mean}_{\text{Post}} - \text{Mean}_{\text{Pre}}$). Median values were also reported in the instances where Likert scale was used for the surveyed parameters. Compared to the mean, median is usually less sensitive to the outliers [46]. The mean values for company-level pre- and post-occupancy data along with differences in means are also reported.

To test the main research hypotheses and considering non-independency of the survey data, linear mixed effects analyses were performed. Linear mixed effects models are used to analyze data from pre-post within-subjects studies when you do not have the exact same sample pre and post. Linear mixed-effects models can also handle unbalanced and missing data better than other methods. To use the linear mixed effects model for this study, first, unique IDs were assigned to the responses that included the participant's email address. Then, dummy IDs were assigned to the remaining responses (less than 24% of the total responses). Next, the linear mixed effects models were carried out using the lme4 R package [47]. In these models, time (pre-occupancy and post-occupancy) was entered as a fixed effect. To be mindful of the possible sources of variance in the available dataset, participant IDs and company labels were included in the models as random effects. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. For p-values below the 0.05 threshold, tests were considered highly significant ($p \leq 0.001$), significant ($0.001 < p \leq 0.01$), and weakly significant ($0.01 < p < 0.05$) [48]. To account for the increase in family-wise error rate across the reported statistical analyses when doing multiple hypothesis testing, p-values were adjusted based on Bonferroni correction method [49].

Since statistical significance can be brought on only due to large sample size [50], effect sizes were calculated to show the practical significance of the differences for each comparison of non-WELL certified and WELL certified offices [51]. For this study, patrial eta-squared (η_p^2) was chosen to calculate the effect sizes. This measure was used to take into account the effects of random effects that were included in the data analysis. Patrial eta-squared is practical in calculating effect sizes from t-test statistics with good accuracy [52]. Effect sizes were calculated using the effectsize R package [53]. The interpretations for the values of effect size are based on the thresholds proposed by Cohen [54]: large ($0.14 \leq \eta_p^2$), medium ($0.06 \leq \eta_p^2 < 0.14$), small ($0.01 \leq \eta_p^2 < 0.06$), and negligible ($\eta_p^2 < 0.01$). There are many effect size indices with different applications and thresholds available. Some similar post-occupancy studies that looked at the effectiveness of WELL [30] and LEED [55] used Spearman's rho to measure the practical significance of their studied variables in their sample. There is currently little, to no, consensus over which thresholds should be adopted in this field of study. Therefore, one should use caution when interpreting the reported effect sizes across similar post-occupancy studies in the literature.

3. Results and discussion

3.1. Description of the dataset

For the pre-occupancy surveys, response rates varied from 42% (company C) to 95% (company A) with an average of 68%. The average response rate for post-occupancy surveys was 56%, varying from 28% (company F) to 88% (company A). Standard ASHRAE 62.1 recommends a minimum response rate of 30%, to decrease the non-response bias [56]. However, a web-based IEQ satisfaction survey conducted by Zagreus et al. [57] reported no statistically significant relationship between response rate and occupant satisfaction levels in multiple case studies.

Table 2 presents the description of the aggregate dataset in terms of number and percentage of occupant responses. With respect to WELL certification level, more than half of the data are from occupants that transitioned into offices WELL certified at the Silver level, which accounts for 59% and 70% of the pre- and post-occupancy responses,

Table 2
Distribution of the occupant responses and their characteristics within the dataset. Percentages represent distribution relative to the total dataset.

		Number of Responses (%)	
		Pre	Post
	Total	700 (100%)	612 (100%)
Company	A	38 (6%)	35 (6%)
	B	22 (3%)	19 (3%)
	C	33 (5%)	53 (9%)
	D	239 (34%)	257 (42%)
	E	176 (25%)	173 (28%)
	F	192 (27%)	75 (12%)
Certification level	Platinum	55 (8%)	72 (12%)
	Gold	230 (33%)	110 (18%)
	Silver	415 (59%)	430 (70%)
Gender	Female	301 (43%)	261 (43%)
	Male	388 (55%)	348 (57%)
	Other	11 (2%)	3 (0%)
Age (years)	30 and under	166 (24%)	160 (26%)
	31 to 40	202 (29%)	176 (29%)
	41 to 50	161 (23%)	132 (21%)
	51 to 60	166 (23%)	140 (23%)
	Above 60	5 (1%)	4 (1%)
Length of employment (years)	Less than 1	109 (15%)	91 (15%)
	1 to 2	138 (20%)	107 (17%)
	3 to 5	154 (22%)	135 (22%)
	Above 5	299 (43%)	275 (45%)
	Not available	0 (0%)	4 (1%)
Hours worked weekly in office	Less than 12	38 (5%)	52 (9%)
	13 to 24	20 (3%)	15 (2%)
	25 to 35	42 (6%)	45 (7%)
	36 to 40	220 (31%)	155 (25%)
	Above 40	347 (50%)	292 (48%)
	Not available	33 (5%)	53 (9%)

respectively. Pre- and post-occupancy responses come from the relatively similar distribution of genders (55% male vs. 43% female in pre-occupancy and 57% male vs. 43% female in post-occupancy). Considering the age of the respondents, responses were approximately equally distributed among groups of below 60 years old. More than 40% of the responses are from occupants that have spent over 5 years at their current company and about half of the responses come from occupants that work more than 40 hours per week in the office.

3.2. Aggregate-level results

3.2.1. Occupant satisfaction

Table 3 presents the statistical analysis results of occupant satisfaction pre- versus post-occupancy. The changes in the means from pre-to post-occupancy were highly statistically significant across all satisfaction parameters ($p \leq 0.001$) studied. The response means for all 12 parameters improved pre- to post-occupancy, with a 1.07-point average improvement on the 7-point Likert scale. Satisfaction with cleanliness, lighting, and access to nature improved the most from pre- to post-occupancy. Among the 12 parameters, eight had large effect sizes and two (i.e., physical activity and wellness programs) had medium effect sizes. The effect sizes calculated for satisfaction with acoustics and access and quality of water were small.

Fig. 1 reveals more insight of the occupant response distribution in the pre- and post-occupancy surveys. The post-occupancy responses were concentrated towards higher satisfaction levels on the 7-point Likert scale compared with pre-occupancy. For parameters with less improvement in means, the 25th percentile shifted towards higher satisfaction levels. The interquartile range for five out of 12 parameters became smaller in post-occupancy, showing smaller variations for the middle 50% of the responses in post-occupancy compared to pre-occupancy. Post-occupancy responses were also more consistently in higher satisfaction levels.

Further breakdown of the satisfaction responses indicates the average overall satisfaction rates across parameters improved from 42% pre-occupancy to 70% post-occupancy, with no drop in overall satisfaction across any parameter (Figure A1). The two largest increases in overall satisfaction were for cleanliness (from 25% to 75%) and access to nature (from 22% to 59%). Occupants were the most satisfied with maintenance (85%) and lighting (84%) in the WELL certified offices. While still improving from pre- to post-occupancy, the largest sources of dissatisfaction in the WELL certified offices were acoustics (35%) and thermal comfort (32%).

Licina and Yildirim [30] studied occupant responses pre- versus post-WELL certification in Europe and found that the mean differences for occupant satisfaction were not statistically significant for more than half of the studied IEQ parameters. In their sample, satisfaction means for some parameters (e.g., outdoor surrounding, amount of light, and visual privacy) declined in some of the buildings. The decrease in satisfaction was statistically significant in some cases. In their study, the effect sizes for parameters ranged from negligible to moderate. In another study, Altomonte and Schiavon [55] evaluated more than 21,

Table 3
Results of statistical analysis of occupant satisfaction pre- versus post-occupancy.

Parameter	Time	Median	Mean (SD)	ΔMean[†]	Effect size[a] η_p^2
Indoor air quality	Pre	0	0.47 (1.54)	1.23***	0.17
	Post	2	1.71 (1.52)		
Thermal comfort	Pre	0	−0.15 (1.65)	0.66***	0.15
	Post	1	0.52 (1.85)		
Physical comfort	Pre	0	0.49 (1.42)	1.20***	0.17
	Post	2	1.69 (1.34)		
Lighting	Pre	1	0.63 (1.58)	1.37***	0.19
	Post	2	2.00 (1.30)		
Acoustics	Pre	0	−0.15 (1.61)	0.48***	0.03
	Post	1	0.34 (1.90)		
Cleanliness	Pre	−1	−0.55 (1.51)	2.02***	0.26
	Post	2	1.47 (1.70)		
Maintenance	Pre	1	0.87 (1.40)	0.97***	0.15
	Post	2	1.84 (1.19)		
Access to nature	Pre	0	−0.40 (1.48)	1.36***	0.18
	Post	1	0.95 (1.55)		
Physical activity	Pre	0	−0.19 (1.62)	0.94***	0.09
	Post	1	0.75 (1.59)		
Access and quality of water	Pre	1	1.03 (1.60)	0.72***	0.04
	Post	2	1.76 (1.51)		
Ability to eat healthy	Pre	0	0.25 (1.58)	1.12***	0.15
	Post	2	1.37 (1.43)		
Wellness programs	Pre	0	0.37 (1.61)	0.75***	0.09
	Post	1	1.12 (1.56)		

[†] ***Highly significant ($p \leq 0.001$), **significant ($0.001 < p \leq 0.01$), and *weakly significant ($0.01 < p < 0.05$).
[a] Large ($0.14 \leq \eta_p^2$), Medium ($0.06 \leq \eta_p^2 < 0.14$), and Small ($0.01 \leq \eta_p^2 < 0.06$).

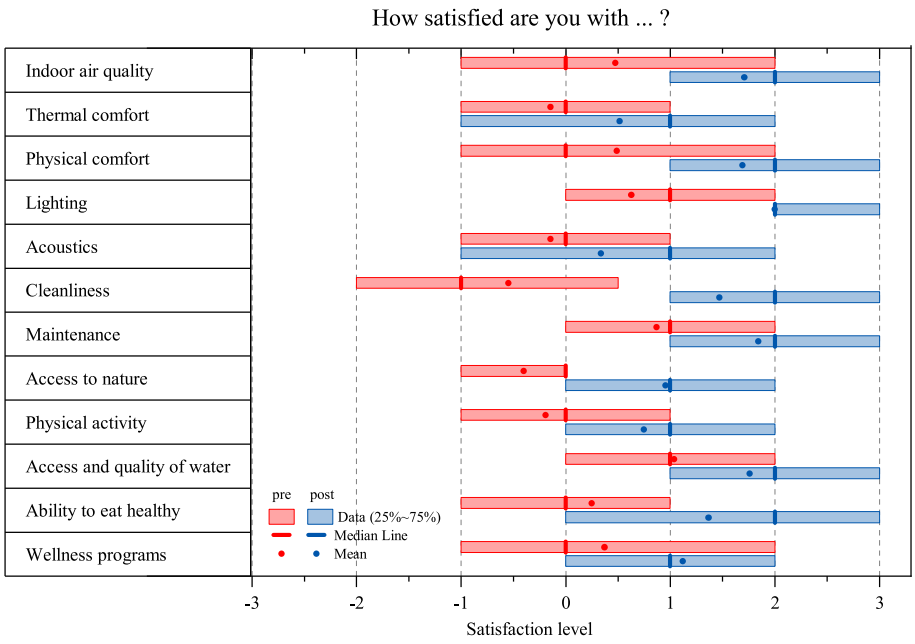

Fig. 1. Pre- versus post-occupancy occupant satisfaction responses. Box charts graphically indicate the concentration of the responses, where boxes represent the interquartile range (25th and 75th percentiles). Means and medians are displayed by bold dots and solid bars, respectively.

000 individual occupant responses and reported statistically significant differences in occupant satisfaction with IEQ between non-LEED and LEED certified buildings across most of their studied parameters. Since statistical significance can be affected by sample size, they calculated effect sizes to study the degree of practicality of the outcomes. They reported negligible effect sizes for all the studied parameters, revealing that the statistical significances were only brought on due to their large sample size.

Candido et al. [29] compared WELL certified offices with non-WELL certified offices and found that WELL certified offices highly outperformed the non-WELL certified offices in satisfaction with connection to outdoor environment and visual comfort. In a post-occupancy evaluation study conducted by Graham et al. [58] on more than 90,000 respondents from nearly 900 buildings (including 692 office buildings), acoustics and temperature were also identified as parameters with the lowest benchmark scores in building occupant satisfaction. Similarly, Huizenga et al. [59] analyzed over 34,000 occupant responses from 215 office buildings and reported that most buildings were "falling far short" in meeting occupant thermal comfort needs. In another study, Abbaszadeh et al. [60] studied indoor environmental quality survey responses of green and non-green certified office building occupants and found comparable means for satisfaction with acoustic quality in green and non-green certified building.

Licina and Yildirim [30] found insignificant differences in occupant satisfaction with noise and sound privacy when comparing the pre- versus post-occupancy IEQ satisfaction responses in non-WELL certified versus WELL certified buildings. Candido et al. [29] also reported that their studied WELL certified offices only slightly outperformed the non-WELL certified offices in satisfaction with noise distraction.

3.2.2. Occupant perceived health

Box plot results for occupant perceived mental and physical health are shown in Fig. 2. The mean occupant perceived mental health score increased from 41.7 (SD_0 = 8.1) to 51.7 (SD_1 = 8.3), and the mean occupant perceived physical health score increased from 53.0 (SD_0 = 5.8) to 55.1 (SD_1 = 5.3) pre-to post-occupancy, respectively. For both parameters, the increases in mean scores were highly statistically significant ($p \leq 0.001$). Effect size calculations revealed large effect size for perceived mental health ($\eta_p^2 = 0.36$) and small effect size for perceived

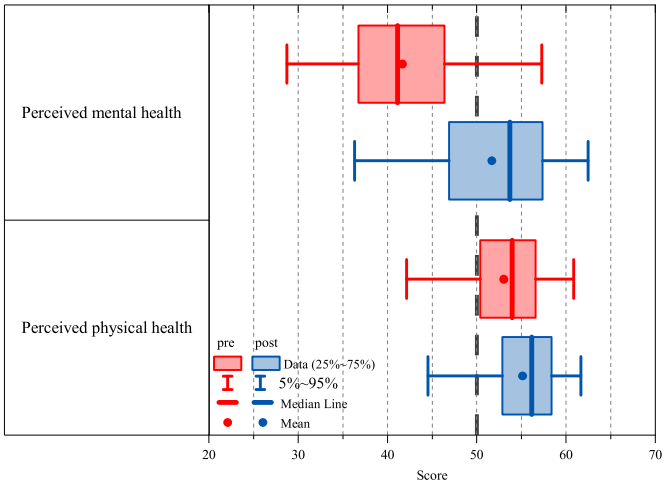

Fig. 2. Box plots of pre- and post-occupancy scores for perceived mental and physical health. Score of 50 (dashed line) represents the U.S. national average.

physical health ($\eta_p^2 = 0.04$).

While the interquartile range for the pre- and post-occupancy scores were similar for both perceived mental and physical health, scores were clustered towards the higher end of the spectrum post-occupancy. This improvement was more evident for perceived mental health, where the second and third quartiles increased from 37 and 46 to 47 and 57, respectively. Minimum and maximum for both perceived health scores improved post-occupancy. Perceived mental and physical health scores in post-occupancy were clustered towards the higher end of the scale. Means and medians were above the U.S. national average score of 50 [61] in post-occupancy. Post-occupancy perceived physical health scores were mostly located around the median, showing less variation and more consistency in the scores.

While no prior studies, to the authors' best knowledge, have quantitatively analyzed the explicit impacts of WELL certification on occupants' perceived mental and physical health, it is widely accepted that the architectural and engineering practices in buildings can affect

perceived occupant health [62,63]. In the study by Thutcher and Milner [64], occupants in one out of the three studied green certified commercial buildings reported improved physical well-being. Candido et al. [29] also reported higher overall perceived health status for WELL certified office occupants compared to the responses came from non-WELL certified offices. Another quantitative research study conducted by MacNaughton et al. [65] reported that the occupants in green certified buildings experienced 30% less SBS symptoms than the occupants in non-green certified buildings. Inconsistent with the findings from MacNaughton [65], Licina and Yildirim [30] found insignificant differences between WELL certified and non-WELL certified offices in the occurrence of SBS symptoms, except for symptom of tiredness. Aligning with the WELL objectives, previously mentioned in Section 1.1, results of the current study suggest that WELL might have contributed to the improvement in perceived occupant health. This improvement was more evident for perceived mental health. Unlike the mean and median of perceived mental health scores, the mean and median perceived physical health scores were above the U.S. national average pre-occupancy, indicating the occupants, on average, had higher perceived physical health prior to transitioning to WELL certified offices, leading to less available room for improvement.

3.2.3. Occupant perceived well-being

Table 4 presents the results of the statistical analysis of occupant perceived well-being pre- versus post-occupancy. Means increased 0.65 points, on average, on the 5-point Likert scale across all the studied parameters. Occupants' agreement with the statements *The workplace* supports *my ability to retreat and have private conversations* (ΔMean = 0.90) and *I wish I worked in another building* (ΔMean = 0.87) increased the most. Differences in means across all parameters were statistically highly significant, with *p*-values less than 0.001. The calculated effect sizes were large for four out of 11 parameters. Four parameters had medium effect sizes and the remaining three parameters had small effect sizes.

Fig. 3 shows the distribution of occupant responses pre-versus post-occupancy. Occupant agreement rates shifted towards higher levels post-occupancy, with the middle half of the responses (25%–75%) across all parameters located in the positive agreement levels (0–2). Distribution of the post-occupancy responses across parameters was very alike, indicating that occupants' perceived well-being was uniformly higher in the WELL certified offices compared to the non-WELL certified offices. On average, the difference between means and medians decreased from 0.29 to 0.14 points from pre- to post-occupancy, suggesting a more balanced distribution in the responses post-occupancy.

While there is a lack of evidence on the effectiveness of health-focused building programs on occupant well-being, in longitudinal studies conducted by Thatcher and Milner [64,66] on green certified commercial buildings' occupants, no significant improvements for occupants' psychological well-being were found. Haapakangas et al. [67] studied four Swedish government agency buildings and reported that activity-based office environment can be related to occupant self-rated well-being. Danielson and Bodin [68] and Danielson et al. [69] suggested that the overall workplace experience and environmental factors such as enterprise-level cultural changes, wellness programs, and improved access to outdoor environment can be positively associated with occupant well-being and mental health. Rashid and Spreckelmeyer [70] studied the effects of environmental design aspects on occupants' organizational image in green buildings and found some evidence for indirect effects of the aspects on occupants' organizational image. This study found a non-negligible correlation between transition to WELL certified offices and the agreement level for the statement *The workplace makes me proud to be a part of this organization* in the aggregate level analysis.

Studying the distribution of the pre- and post-occupancy responses showed that the agreement rates with statements associated to their well-being were considerably higher post-occupancy compared to pre-occupancy (Figure A2). The average overall agreement rate improved from 46% to 72% from pre- to post-occupancy, with no decline in overall agreement rate across the parameters. Overall disagreement with the well-being statements decreased from 23% to 9%. Average percentage of neutral responses was smaller post-occupancy (19%) compared to the pre-occupancy (31%), indicating that occupants were more willing to provide an opinion in the post-occupancy survey. Graham et al. [58] also suggests that large percentage of neutral responses in occupant surveys can show that these questions are harder to answer.

Table 4
Results of statistical analysis of occupant perceived well-being pre- versus post-occupancy.

Parameter	Time	Median	Mean (SD)	ΔMean[†]	Effect size[a] η_p^2
The workplace makes me …					
energized.	Pre	0	0.14 (1.05)	0.64***	0.11
	Post	1	0.78 (0.99)		
motivated to work.	Pre	1	0.59 (1.04)	0.41***	0.05
	Post	1	1.00 (0.99)		
excited about coming to work.	Pre	1	0.60 (1.02)	0.36***	0.04
	Post	1	0.96 (1.00)		
wish I worked in another building.[b]	Pre	0	−0.01 (1.18)	0.87***	0.13
	Post	1	0.85 (1.26)		
proud to be a part of this organization.	Pre	1	0.50 (1.01)	0.80***	0.17
	Post	1	1.30 (0.83)		
The workplace supports my …					
thinking and analytical work.	Pre	0	0.38 (1.02)	0.46***	0.06
	Post	1	0.83 (1.05)		
ability to retreat and have private conversations	Pre	0	−0.18 (1.27)	0.90***	0.14
	Post	1	0.73 (1.27)		
The workplace …					
is conducive to my health and well-being.	Pre	0	0.15 (1.03)	0.72***	0.16
	Post	1	0.88 (0.97)		
facilitates collaborative working.	Pre	1	0.51 (1.02)	0.65***	0.11
	Post	1	1.16 (0.93)		
helps to have chance meetings.	Pre	0	0.24 (0.99)	0.68***	0.13
	Post	1	0.91 (1.02)		
The organization cares about how …					
the physical work environment impacts mental health.	Pre	0	0.35 (1.10)	0.73***	0.14
	Post	1	1.07 (0.93)		

[†] ***Highly significant ($p \leq 0.001$), **significant ($0.001 < p \leq 0.01$), and *weakly significant ($0.01 < p < 0.05$).
[a] Large ($0.14 \leq \eta_p^2$), Medium ($0.06 \leq \eta_p^2 < 0.14$), and Small ($0.01 \leq \eta_p^2 < 0.06$).
[b] Occupant responses have been reverse coded.

3.2.4. Occupant perceived productivity

Fig. 4 shows the distribution of occupants' presenteeism scores pre-versus post-occupancy. As stated in subsection 2.3, as a measure of perceived productivity, presenteeism score (from 0 to 100) indicates the lack of job performance during time on the job, with higher scores

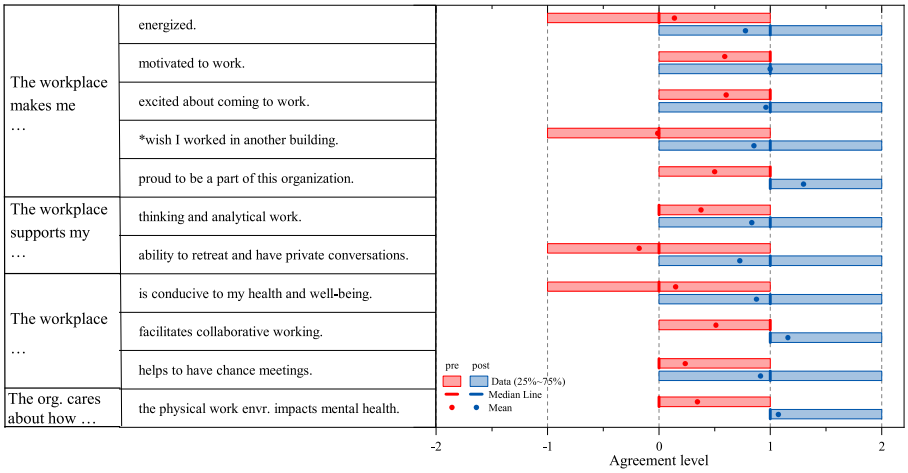

Fig. 3. Box plots of pre- versus post-occupancy occupant perceived well-being responses. *Occupant responses have been reverse coded.

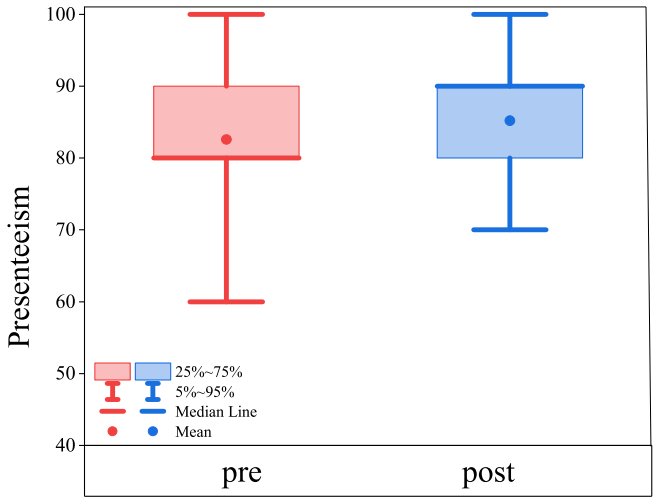

Fig. 4. Occupant pre- and post-occupancy presenteeism scores.

suggesting a lower amount of lost performance. Mean presenteeism score increased from 82.6 ($SD_0 = 12.6$) to 85.2 ($SD_1 = 11.8$) pre-to post-occupancy. The change in mean from pre- to post-occupancy was statistically highly significant ($p \leq 0.001$). However, the statistical analysis revealed that this change had a small effect size ($\eta_p^2 = 0.01$), implying that the statistical significance was brought on due to the large sample size.

From pre- to post-occupancy the median presenteeism score improved from 80.0 to 90.0. The interquartile ranges were similar for the pre- and post-occupancy scores (from 80.0 to 90.0), suggesting a similar spread of the middle 50% of productivity scores pre- and post-occupancy. However, the range of scores post-occupancy was smaller compared to the pre-occupancy scores, where the minimum of productivity scores was higher in post-occupancy. This indicates that the post-occupancy productivity scores were overall higher than the pre-occupancy productivity scores. Furthermore, the mean post-occupancy score is lower than the median value, which indicates that the post-occupancy scores were negatively skewed with a tail of low scores pulling down the mean. In contrast, some extremely high scores resulted in the mean pre-occupancy score being higher than median value.

Unlike the findings of this study, Licina and Yildirim [30] reported insignificant differences in occupant self-reported productivity between non-WELL certified versus WELL certified buildings in their sample. However, their sample sizes are considerably smaller than the current study. In another study, Thatcher and Milner [71] compared the differences between pre- and post-occupancy responses of two distinct groups: a group that moved to a green certified building from a conventional building, and a group that did not move. They found no significant improvement in perceived productivity measures of a group that moved to the green building compared to the other group. In contrast, Candido et al. [29] reported higher overall self-rated productivity for WELL certified office occupants compared to the non-WELL certified offices. Haapakangas et al. [67] also found that activity-based office environments are related to occupant productivity and that satisfaction with the physical environment, improved privacy and communication are positively correlated to workplace well-being and self-rated productivity. They also found associations with the time lost in searching for a suitable workspace and lower self-reported productivity.

3.3. Company-level results

3.3.1. Occupant satisfaction

Fig. 5 depicts changes in mean from pre- to post-occupancy across the six companies. The average mean improvement across satisfaction parameters for each company varied from 0.77 points (company D) to 2.07 points (company B) on the 7-point Likert scale. Companies B and D, respectively, achieved the highest and lowest number of WELL features which might have contributed to seeing these average improvements of means. However, there was not a proportional relationship between total relevant achieved WELL features and improvement of mean.

Satisfaction means improved for all parameters, except for three instances where the satisfaction means dropped significantly pre- to post-occupancy. These cases include cleanliness in company F (ΔMean $= -1.05$), access and quality of water in company E (ΔMean $= -0.78$), and acoustics in company D (ΔMean $= -0.18$). Despite company F achieving the same or higher number of WELL features related to cleaning as companies A, C, D and E, satisfaction with cleanliness in none of these companies decreased. It is worth noting that workplace cleanliness can be affected by factors beyond those addressed by WELL (e.g., contract agreement with environmental services). Thus, further investigation is needed to identify the underlying reasons behind the decrease in occupant satisfaction. Lower post-occupancy satisfaction with water quality in company E goes against what one would intuitively expect. WELL performance verification tests showed Company E had lower levels of turbidity and nitrate in their water than the other companies, indicating higher water quality. Company D's performance verification measurements for one of the enclosed offices and a conference room exceeded the maximum noise criteria threshold (WELL Feature 75) (Table A.3). Company D also achieved the least number of

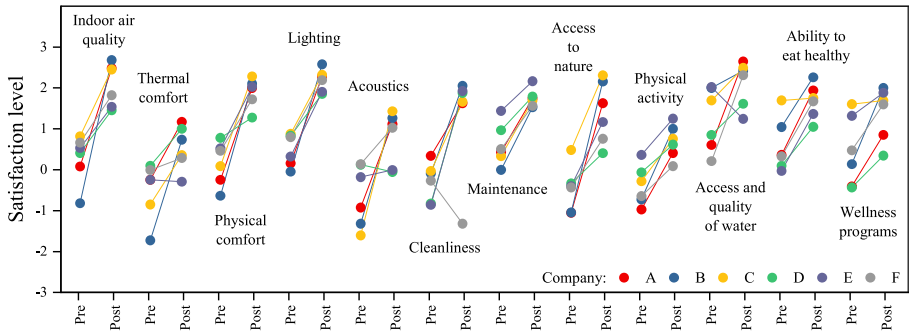

Fig. 5. Comparison between means of pre- and post-occupancy occupant satisfaction responses by each variable on the 7-point Likert scale across the six companies.

WELL acoustics-related features among the companies (Table A.2). Further details of the descriptive analyses are included in Table A.4.

3.3.2. Occupant perceived health

Fig. 6 depicts the pre- versus post-occupancy occupant perceived mental and physical health scores across the six companies. From pre- to post-occupancy, improvement in mean perceived mental health scores ranged from 1.90 (company C) to 14.00 (company D). Changes in the perceived physical health scores ranged from −0.86 (decline for company C) to 2.65 (company D). Company D and E (ΔMean = 13.46) had the most noticeable increase in occupant perceived mental health scores. These companies had the lowest pre-occupancy perceived mental health scores which had likely provided more space for improvements. Company C had the lowest improvement in mean perceived mental health score and was the only company with a decrease in mean occupant perceived physical health score, however, the decrease in mean perceived physical health score was not statistically significant. Further analyses on the scores from company C showed extreme outliers in lower perceived mental and physical health score ranges existed post-occupancy. Further details of the descriptive analyses for health at the company-level are included in Table A.5.

3.3.3. Occupant perceived well-being

As seen in Fig. 7, means across all well-being parameters increased considerably for all companies. The average improvement of mean across all parameters for each company varied from 0.44 points (company D) to 1.39 points (company B) on the 5-point Likert scale. No decreases in response means for any parameters at the company level was found. It is worth noting that company D and company B were reported as the companies with the lowest and highest average improvement in satisfaction means, respectively (subsection 3.3.1). Similarly, company A had the second highest mean satisfaction improvement rates among the companies and had the second highest mean in well-being improvement. Further in-depth correlation analyses are required to investigate the possible relationship between occupant satisfaction and their perceived well-being. All the post-occupancy agreement response means were positive (0–2), indicating consistent perceived well-being among occupants. Further details of the descriptive analyses for well-being responses at the company level are included in the Appendix (Table A.6).

3.3.4. Occupant perceived productivity

As shown in Fig. 8, the mean presenteeism scores improved across all companies. Improvements ranged from 1.39 (company D) to 6.72 (company B). The pre-occupancy means varied from 74.86 (company A) to 86.55 (company C). Post-occupancy, the means ranged from 80.00 (company A) to 91.95 (company C). Presenteeism scores ranged from 40 to 100 pre-occupancy and from 50 to 100 for post-occupancy, indicating a 10-point increase of the minimum value across all companies.

A positive change in presenteeism scores was the most evident for company B (ΔMean = 6.72). This company had the largest improvement in satisfaction means (subsection 3.3.1) and well-being (subsection 3.3.3). Changes in means were smaller for companies D (ΔMean = 1.39) and E (ΔMean = 2.19); however, post-occupancy median scores considerably improved for both companies. Further analyses of companies D and E showed there were extreme outliers in lower score ranges

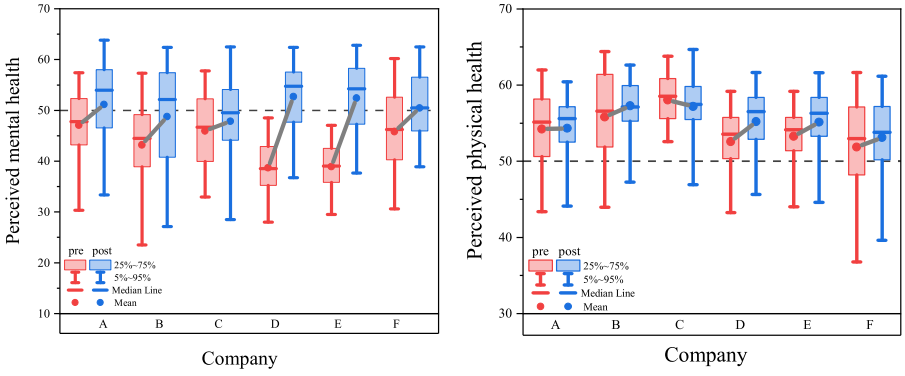

Fig. 6. Pre- versus post-occupancy perceived mental (left) and physical (right) health scores by company. Score of 50 (dashed line) represents the U.S. national average.

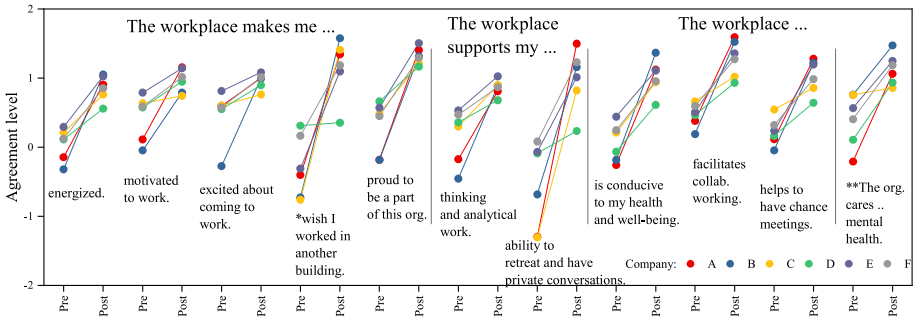

Fig. 7. Comparison between pre- and post-occupancy means for each perceived well-being parameter on the 5-point Likert scale across the six companies. * Mean values have been reverse coded. **The organization cares about how the physical work environment impacts mental health.

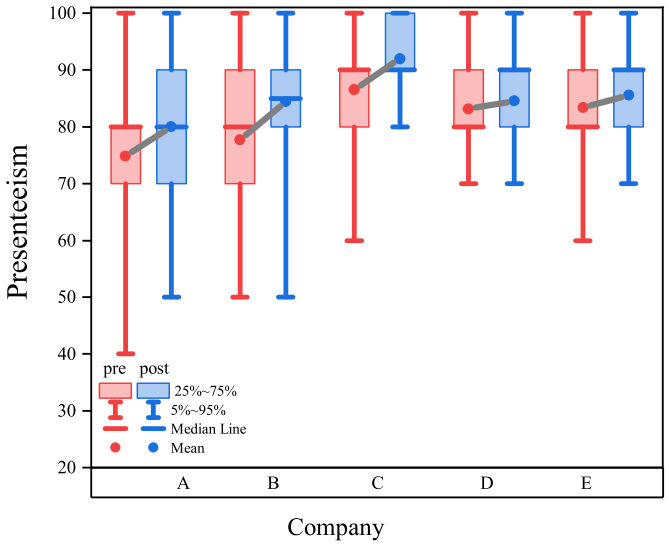

Fig. 8. Pre- versus post-occupancy perceived productivity scores for five of the six companies.

both pre- and post-occupancy. Perceived productivity data for company F was not available. Further details of the descriptive analyses for perceived productivity are included in Table A.5.

4. Study limitations

Some minor limitations to this study should be considered. Firstly, this study cannot determine with certainty that the observed changes in occupant satisfaction and perceptions were caused by WELL certification per se. WELL certification happened in conjunction with other design changes beyond those required by WELL across all companies, although this study did its best to control for those variables. Several studies have shown factors such as personal characteristics (e.g., age and gender) and type of work can also affect occupant satisfaction with the indoor environment [8,72]. This study did not examine the potential moderating effects of these variables. This study also did not control for variables around psychosocial stress (e.g., job support, job control, and job demand) that could affect occupant perceptions of workplace well-being [73,74]. Future study that combines environmental design and organizational psychology research may reveal remarkable dynamics between aforementioned areas.

Secondly, although surveys are useful in measuring occupant satisfaction and perceptions, subjective measurements can be biased. For example, the fact that occupants were aware they were part of a study could have altered their survey responses, a phenomenon known as the "Hawthorne Effect" [48,75,76]. Occupants likely knew their offices were WELL-certified which may have also created bias in their satisfaction and perceptions [31,77]. A multi-method research approach that includes objective environmental, productivity, and health measures as well as subjective survey data would allow for data triangulation, increasing the reliability of the results.

Lastly, some of the post-occupancy surveys were administered less than a year after the employees began occupying the WELL-certified offices, which could have led to more positive results due to the newness of the offices [8]. Further research needs to be conducted to investigate the long-term impact of WELL certification on the variables examined in this study to determine if the same results continue to be found in subsequent years.

5. Conclusion

This paper comprehensively studied the impact of WELL certification on occupant satisfaction and perceived health, well-being, and productivity using more than 1300 pre- and post-occupancy survey responses from six companies. Pre- versus post-occupancy analyses were conducted at both the aggregate and company level. Results of the aggregate analyses showed that occupant satisfaction and perceived health, well-being, and productivity improved from pre- to post-occupancy with the changes in means across all the studied parameters being highly statistically significant. The effect sizes varied from small to large across the studied parameters.

- Occupants were more satisfied in WELL certified offices, with means across all 12 studied parameters, improving 1.1 points, on average, on the 7-point Likert scale. Effect sizes were large for eight of twelve the studied parameters. Two parameters had medium effect sizes (physical activity and wellness programs), and two had small effect sizes (acoustics and access and quality of water).
- Occupants reported higher perceived health in the WELL certified offices than in the non-WELL certified offices. Perceived mental and physical health means improved from 41.7 to 51.7 and from 53.0 to 55.1, respectively, on a scale of 0–100. Effect sizes revealed large and small practical significance, respectively, for changes in perceived mental and physical health scores from pre- to post-occupancy.
- Occupant agreement rates to statements associated with their well-being were considerably higher in the WELL certified offices, with a 0.7-point improvement in means, on average, on the 5-point Likert scale. The majority of the effect sizes calculated for the perceived

well-being parameters were large or medium, indicating non-negligible practical significance.
- Occupants reported higher productivity levels in the WELL certified offices compared to the non-WELL certified offices. The self-assessed productivity mean score increased from 82.6 to 85.2 on a 0–100 scale from pre- to post-occupancy. However, the effect size was small.

When speaking of the effect sizes, the terms "small", "medium" and "large" are relative to each other, and their interpretations are specific to the content and research method being used in this study. Therefore, caution needs to be exercised when performing future cross-study comparisons (e.g., meta-analysis) to avoid inconsistent interpretations.

Occupant responses to the pre- and post-occupancy surveys were also studied by company. Satisfaction means for most parameters improved from pre- to post-occupancy across all companies. A uniform increase in means for perceived well-being parameters was noticed. Perceived mental health and productivity means improved across all companies. The results and performance verification data provided in this study can support future research to analyze and reproduce the outcomes of this study.

CRediT authorship contribution statement

Nasim Ildiri: Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Conceptualization. **Heather Bazille:** Writing – review & editing, Resources, Conceptualization. **Yingli Lou:** Writing – review & editing, Visualization. **Kathryn Hinkelman:** Writing – review & editing. **Whitney A. Gray:** Supervision, Resources. **Wangda Zuo:** Supervision.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Whitney Austin Gray reports financial support was provided by Delos Living LLC. Whitney Austin Gray reports a relationship with International WELL Building Institute pbc that includes: employment. Heather Bazille reports a relationship with International WELL Building Institute pbc that includes: employment.

Data availability

The data that has been used is confidential.

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Appendix

Table A.1
Building Wellness Survey items and Likert scales used to measure occupant satisfaction and perceived well-being

Variable	Building Wellness Survey Item	Likert Scale
Occupant Satisfaction	How satisfied are you with the indoor air quality where you work in terms of being breathable, clean, and odorless?	7-point Very Satisfied to Very Dissatisfied
	How satisfied are you with the thermal comfort in your workplace (issues related to temperature, humidity, and air movement)?	
	How satisfied are you with your physical comfort in your workplace (issues around comfort with the furniture and overall layout of the space)?	
	Overall, how satisfied are you with the lighting in your workplace?	
	Overall, how satisfied are you with the acoustics in your workplace (e.g., noise levels, ability to hear others, and sound privacy)?	
	Please rate your satisfaction with the level of overall cleanliness of your workplace.	
	Please rate your satisfaction with the level of overall maintenance of your workplace.	
	Rate your satisfaction with the access to nature in your workplace (exposure to the natural environment, e.g., plants, gardens, artwork/furniture/designs depicting or resembling natural environments, etc.).	
	Overall, how satisfied are you with your level of physical activity throughout the day (all movement including standing, climbing stairs, walking, bicycling, etc.)?	
	Overall, how satisfied are you with the accessibility and quality of drinking water in your workplace?	
	Overall, how satisfied are you with your ability to eat healthy at your workplace?	
	Please indicate to what extent you agree with this statement: My workplace provides and supports workplace wellness programs (e.g., childcare support, health and wellness benefits, flexible hours, stress reduction programs)?	7-point Fully Agree to Fully Disagree
Occupant Perceived Well-Being	The workplace energizes me	5-point Strongly Agree to Strongly Disagree
	The workplace is conducive to my health and well-being	
	I feel motivated to work at my best everyday	
	The workplace supports my thinking and analytical work	
	I look forward to coming to work	
	I wish I worked in another building	
	The workplace makes me proud to be part of this organization	
	The workplace supports my ability to retreat and have private conversations	
	It is easy to work collaboratively with others	
	The workplace creates an opportunity for chance meetings helping us to reveal opportunities	
	The organization cares about how the physical work environment impacts mental health	

Table A.2
Mapping of satisfaction parameters studied in the paper with the relevant WELL features achieved by company. P/O stands for precondition/optimization (required/optional feature). An X means the feature was achieved.

Parameter	WELL Concept	P/O	WELL Feature	Company					
				A	B	C	D	E	F
Indoor	Air	P	01 Air Quality Standards	X	X	X	X	X	X
Air	Air	P	02 Smoking Ban	X	X	X	X	X	X
Quality	Air	P	03 Ventilation Effectiveness	X	X	X	X	X	X
	Air	P	04 VOC Reduction	X	X	X	X	X	X
	Air	P	05 Air Filtration	X	X	X	X	X	X
	Air	P	06 Microbe and Mold Control	X	X	X	X	X	X
	Air	P	07 Construction Pollution Management	X	X	X	X	X	X
	Air	O	08 Healthy Entrance		X	X	X		X
	Air	P	09 Cleaning Protocol	X	X	X	X	X	X
	Air	P	11 Fundamental Material Safety	X	X	X	X	X	X
	Air	O	13 Air Flush		X	X			X
	Air	O	14 Air Infiltration Management						X
	Air	O	15 Increased Ventilation	X		X			
	Air	O	16 Humidity Control						
	Air	O	17 Direct Source Ventilation	X	X	X			
	Air	O	18 Air Quality Monitoring and Feedback	X	X	X			
	Air	O	19 Operable Windows			X			
	Air	O	20 Outdoor Air Systems						
	Air	O	21 Displacement Ventilation	X		X			
	Air	O	22 Pest Control	X	X	X			
	Air	O	23 Advanced Air Purification		X				
	Air	O	24 Combustion Minimization	X	X	X	X	X	X
	Air	O	25 Toxic Material Reduction	X	X	X			
	Air	O	26 Enhanced Material Safety		X	X			
	Air	O	27 Antimicrobial Activity for Surfaces		X	X			
	Air	O	28 Cleanable Environment	X	X			X	X
	Air	O	29 Cleaning Equipment	X	X	X	X	X	X
	Comfort	O	77 Olfactory Comfort			X			X
Thermal	Comfort	P	76 Thermal Comfort	X	X	X	X	X	X
Comfort	Comfort	O	82 Individual Thermal Control	X	X	X			
	Comfort	O	83 Radiant Thermal Comfort						
Physical	Fitness	O	71 Active Furnishings	X	X	X			
Comfort	Comfort	P	72 Accessible Design	X	X	X	X	X	X
	Comfort	P	73 Ergonomics: Visual and Physical	X	X	X	X	X	X
	Mind	P	88 Biophilia I - Qualitative	X	X	X	X	X	X
	Mind	O	89 Adaptable Spaces	X	X	X			X
	Mind	O	99 Beauty and Design II	X	X	X			
Lighting	Light	P	53 Visual Lighting Design	X	X	X	X	X	X
	Light	P	54 Circadian Lighting Design	X	X	X	X	X	X
	Light	P	55 Electric Light Glare Control	X	X	X	X	X	X
	Light	P	56 Solar Glare Control	X	X	X	X	X	X
	Light	O	57 Low-Glare Workstation Design	X	X	X			X
	Light	O	58 Color Quality	X	X	X		X	
	Light	O	59 Surface Design	X	X			X	
	Light	O	60 Automated Shading and Dimming Controls		X				
	Light	O	61 Right to Light	X	X	X			X
	Light	O	62 Daylight Modeling		X	X			
	Light	O	63 Daylighting Fenestration	X					
	Mind	P	88 Biophilia I - Qualitative	X	X	X	X	X	X
Acoustics	Comfort	O	74 Exterior Noise Intrusion	X	X	X	X	X	X
	Comfort	P	75 Internally Generated Noise	X	X	X	X	X	X
	Comfort	O	78 Reverberation Time	X	X				X
	Comfort	O	79 Sound Masking		X	X			X
	Comfort	O	80 Sound Reducing Surfaces	X	X			X	
	Comfort	O	81 Sound Barriers	X	X			X	
Cleanliness	Air	O	08 Healthy Entrance		X	X	X		X
	Air	P	09 Cleaning Protocol	X	X	X	X	X	X
	Air	O	27 Antimicrobial Activity for Surfaces		X	X			
	Air	O	28 Cleanable Environment	X	X			X	X
	Air	O	29 Cleaning Equipment	X	X	X	X	X	X
Maintenance	Mind	P	85 Integrative Design	X	X	X	X	X	X
Access to Nature	Mind	P	88 Biophilia I - Qualitative	X	X	X	X	X	X
	Mind	O	100 Biophilia II - Quantitative						
Physical	Fitness	O	64 Interior Fitness Circulation			X		X	
Activity	Fitness	P	65 Activity Incentive Programs	X	X	X	X	X	X
	Fitness	O	66 Structured Fitness Opportunities	X	X	X		X	
	Fitness	O	67 Exterior Active Design	X	X	X	X		X
	Fitness	O	68 Physical Activity Spaces		X			X	
	Fitness	O	69 Active Transportation Support	X		X			
	Fitness	O	70 Fitness Equipment		X			X	
	Fitness	O	71 Active Furnishings	X	X	X			
Access and Quality of Water	Water	P	30 Fundamental Water Quality	X	X	X	X	X	X

(*continued on next page*)

Table A.2 (*continued*)

Parameter	WELL Concept	P/O	WELL Feature	Company					
				A	B	C	D	E	F
	Water	P	31 Inorganic Contaminants	X	X	X	X	X	X
	Water	P	32 Organic Contaminants	X	X	X	X	X	X
	Water	P	33 Agricultural Contaminants	X	X	X	X	X	X
	Water	P	34 Public Water Additives	X	X	X	X	X	X
	Water	O	35 Periodic Water Quality Testing		X	X			
	Water	O	36 Water Treatment		X	X			X
	Water	O	37 Drinking Water Promotion	X	X	X			
Ability to Eat Healthy	Nourishment	P	38 Fruits and Vegetables	X	X	X	X	X	X
	Nourishment	P	39 Processed Foods	X	X	X	X	X	X
	Nourishment	P	40 Food Allergies	X	X	X	X	X	X
	Nourishment	P	41 Hand Washing	X	X	X	X	X	X
	Nourishment	P	42 Food Contamination	X	X	X	X	X	
	Nourishment	P	43 Artificial Ingredients	X	X	X	X	X	X
	Nourishment	P	44 Nutritional Information	X	X	X	X	X	X
	Nourishment	P	45 Food Advertising	X	X	X	X	X	X
	Nourishment	O	46 Safe Food Preparation Materials	X	X	X			
	Nourishment	O	47 Serving Sizes		X	X			X
	Nourishment	O	48 Special Diets	X	X	X	X	X	X
	Nourishment	O	49 Responsible Food Production		X	X			
	Nourishment	O	50 Food Storage	X	X	X		X	X
	Nourishment	O	51 Food Production						
	Nourishment	O	52 Mindful Eating	X	X	X		X	X
Wellness Programs	Mind	O	90 Healthy Sleep Policy	X	X	X			X
	Mind	O	91 Business Travel		X	X			
	Mind	O	92 Building Health Policy	X	X	X	X	X	X
	Mind	O	93 Workplace Family Support		X	X			X
	Mind	O	94 Self-Monitoring	X	X	X			
	Mind	O	95 Stress and Addiction Treatment	X	X	X	X	X	X

Table A.3
WELL performance verification results for required WELL features (preconditions) by company.

Parameter	WELL Feature	Measurement (unit)	Threshold	Company					
				A	B	C	D	E	F
Indoor Air Quality	01 Air Quality Standards	Formaldehyde (ppb)	<27	5.2–5.7	25	6–7	15.97–21.4	12–23	10.4–11
		TVOC (μg/m^3)	<500	190–260	340–460	240–330	450–460	130–370	23–38
		Carbon monoxide (ppm)	<9	0	0	0	0	0.1–0.8	0.4–0.6
		PM2.5 (ug/m3)	<15	1.5–2	0.2–0.23	1	0.2–0.6	3.68–5.49	4.7–5.4
		PM10 (ug/m3)	<50	2	5.64–7.87	1	7.4–14.6	12.49–37.04	18–30.7
		Ozone (ppb)	<51	0	0	2–3	0	0–7	<10
		Radon (pCi/L)	<4	N/A	N/A	N/A	N/A	<0.6 ± 0.2	N/A
Thermal Comfort	76 Thermal Comfort	Dry Bulb Temperature	ASHRAE 55-2013	70.2–72.9	73.7–75.2	72.5–76.3	–	72.1–73.5	–
		Mean Radiant Temperature	ASHRAE 55-2013	71.2–73.4	N/A	N/A	N/A	N/A	N/A
		Relative Humidity	ASHRAE 55-2013	61–62.4	37.4–39.5	17.3–22	–	49.8–59.1	–
Lighting	53 Visual Lighting Design	Average ambient light intensity (lux)	≥215	567	419	514	628	292	376
Acoustics	75 Internally Generated Noise[†">†]	Open office spaces and lobbies noise criteria (NC)	≤40	35–48	38	40	37	36	35
		Enclosed offices noise criteria (NC)	≤35	N/A	29	30	17–36	23–36	35
		Conference and breakout rooms noise criteria (NC)	≤30	33–36	30–39	28	19–32	23–28	35–40
Water Quality and Access	30 Fundamental Water Quality	Turbidity (NTU)	<1	0.15–0.17	0.17–0.19	0.9–0.95	0.67	0.09–0.16	0.19–0.27
		Total coliforms	ND	ND	ND	ND	ND	ND	ND
		E. coli	ND	ND	ND	ND	ND	ND	ND
	31 Inorganic Contaminants	Lead (mg/L)	<0.01	ND	ND	ND	ND	ND	<0.002
		Arsenic (mg/L)	<0.01	ND	ND	ND	ND	ND	<0.003
		Antimony (mg/L)	<0.006	ND	ND	ND	ND	ND	<0.003
		Mercury (mg/L)	<0.002	ND	ND	ND	ND	ND	<0.0001
		Nickel (mg/L)	<0.012	ND	ND	ND	ND	ND	<0.0030
		Copper (mg/L)	<1	ND	0.02	0.23	0.09	0.05–0.08	0.043
	32 Organic Contaminants	Styrene (mg/L)	<0.0005	ND	ND	ND	ND	ND	<0.0001
		Benzene (mg/L)	<0.001	ND	ND	ND	ND	ND	<0.0002
		Ethylbenzene (mg/L)	<0.3	ND	ND	ND	ND	ND	<0.0001
		Polychlorinated biphenyls (mg/L)	<0.0005	ND	ND	ND	ND	ND	<0.0001
		Vinyl Chloride (mg/L)	<0.002	ND	ND	ND	ND	ND	<0.0002

(*continued on next page*)

Table A.3 (*continued*)

Parameter	WELL Feature	Measurement (unit)	Threshold	Company					
				A	B	C	D	E	F
		Toluene (mg/L)	<0.15	ND	ND	ND	ND	ND	<0.0002
		Xylenes (total: m, p, and o) (mg/L)	<0.5	ND	ND	ND	ND	ND	<0.0002
		Tetrachloroethylene (mg/L)	<0.005	ND	ND	ND	ND	ND	<0.0002
	33 Agricultural Contaminants	Atrazine (mg/L)	<0.001	ND	ND	ND	ND	ND	<0.00
		Simazine (mg/L)	<0.002	ND	ND	ND	ND	ND	<0.00
		Glyphosate (mg/L)	<0.7	ND	ND	ND	ND	ND	<0.02
		2,4-Dichlorophenoxyacetic acid (mg/L)	<0.07	ND	ND	ND	ND	ND	<0.0005
		Nitrate (mg/L)	<50	1.1364	10.9091	ND	0.9091	3.9091	2.0455
	34 Public Water Additives	Total chlorine (mg/L)	<4	–	0	0	0.14	0.21–0.27	0
		Chloramine (mg/L)	<4	–	0	0.07	0.21	1.8–2.23	0.02
		Total trihalomethanes (mg/L)	<0.08	–	ND	0.0284	0.03	0.02	0.0154
		Total haloacetic acid (mg/L)	<0.06	–	ND	0.0052	0.03	0.02	0.0045
		Fluoride (mg/L)	<4	–	0.84	0.82	0.8	0.78	0.57

†">†For companies A, E, and F, an alternative adherence path was applied that allowed noise criteria levels of five higher but limited the project to Gold level, no matter how many optimizations were achieved. For company B, an alternative adherence path was applied that allowed a maximum noise criteria level of 40 for one conference room that exceeded the feature's maximum threshold of 30 for conference rooms. For company D, the results for one conference room and one enclosed office were above the required noise criteria thresholds, but compliance was not affected because the source of noise was an AV equipment closet on the wall adjoining the two spaces.

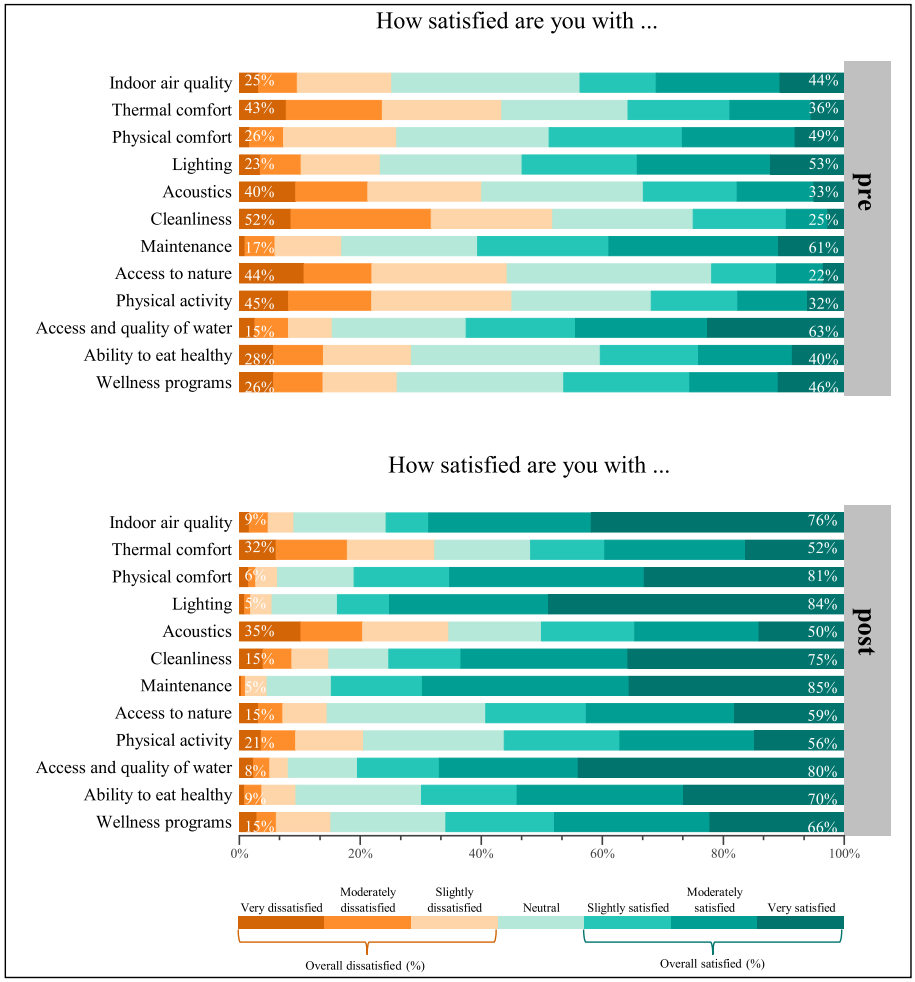

Fig. A.1. Pre- and post-occupancy occupant satisfaction rates.

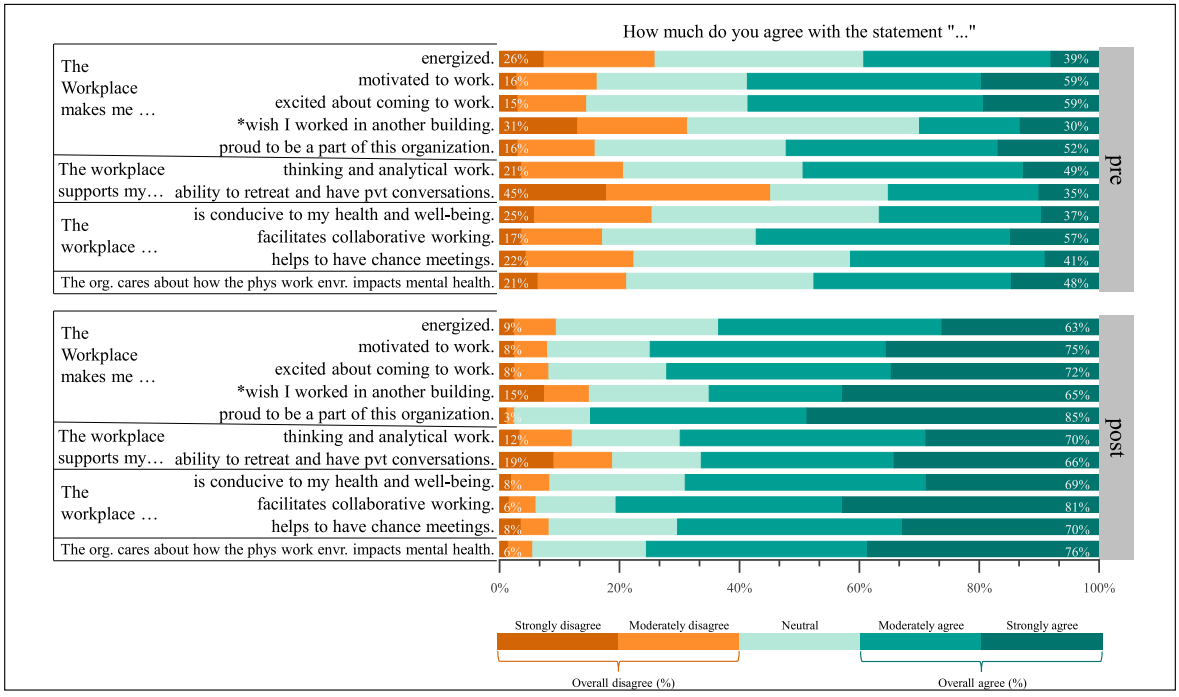

Fig. A.2. Pre- and post-occupancy occupant agreement rates with items related to well-being. *Agreement rates have been switched.

Table A.4
Results of descriptive statistical analysis of occupant satisfaction in the six companies pre- and post-occupancy.

	Company A			Company B			Company C			Company D			Company E			Company F		
Parameter	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM
Indoor air quality	0.08	2.49	2.40	−0.82	2.68	3.50	0.82	2.45	1.63	0.41	1.46	1.05	0.53	1.54	1.01	0.66	1.82	1.16
Thermal comfort	−0.24	1.17	1.41	−1.73	0.74	2.46	−0.85	0.36	1.21	0.10	1.00	0.90	−0.25	−0.29	−0.05	−0.01	0.29	0.29
Physical comfort	−0.24	2.00	2.24	−0.64	2.11	2.74	0.09	2.28	2.19	0.78	1.27	0.49	0.52	2.03	1.50	0.46	1.72	1.26
Lighting	0.16	2.29	2.13	−0.05	2.58	2.62	0.88	2.32	1.44	0.83	1.85	1.02	0.32	1.90	1.58	0.80	2.19	1.40
Acoustics	−0.92	1.12	2.04	−1.32	1.26	2.58	−1.61	1.43	3.04	0.12	−0.05	−0.18	−0.18	−0.01	0.17	0.14	1.03	0.89
Cleanliness	0.34	1.63	1.29	−0.09	2.05	2.14	−0.03	1.66	1.69	−0.82	1.88	2.70	−0.86	1.93	2.78	−0.27	−1.32	−1.05
Maintenance	0.43	1.74	1.31	0.00	1.53	1.53	0.33	1.70	1.36	0.97	1.79	0.83	1.44	2.16	0.72	0.51	1.56	1.06
Access to nature	−1.05	1.63	2.68	−1.05	2.16	3.20	0.48	2.31	1.82	−0.33	0.40	0.74	−0.40	1.17	1.57	−0.43	0.76	1.19
Physical activity	−0.97	0.41	1.38	−0.73	1.00	1.73	−0.28	0.76	1.04	−0.06	0.62	0.68	0.36	1.25	0.89	−0.64	0.09	0.73
Access and quality of water	0.61	2.65	2.04	2.00	2.42	0.42	1.70	2.49	0.79	0.86	1.62	0.76	2.02	1.24	−0.78	0.21	2.31	2.10
Ability to eat healthy	0.36	1.94	1.58	1.05	2.26	1.22	1.70	1.75	0.06	0.10	1.05	0.95	−0.03	1.37	1.40	0.33	1.68	1.35
Wellness programs	−0.41	0.85	1.26	0.14	2.00	1.86	1.61	1.69	0.09	−0.43	0.35	0.78	1.32	1.88	0.56	0.48	1.60	1.12
Average ΔM	1.81			2.17			1.36			0.89			0.95			0.96		

Note: M_0 and M_1 denote means pre- and post-occupancy, respectively. $\Delta M = M_1 - M_0$.

Table A.5
Results of descriptive statistical analysis of occupant perceived health and productivity in the six companies pre-versus post-occupancy.

	Company A			Company B			Company C			Company D			Company E			Company F		
	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM
Perceived Health																		
Mental health	47.10	51.17	4.07	43.18	48.79	5.61	45.95	47.84	1.90	38.67	52.68	14.00	38.95	52.40	13.46	45.82	50.45	4.64
Physical health	54.23	54.32	0.09	55.81	57.29	1.48	58.05	57.19	−0.86	52.55	55.20	2.65	53.26	55.14	1.87	51.87	53.11	1.24
Perceived Productivity																		
Presenteeism	74.86	80.00	5.14	77.73	84.44	6.72	86.55	91.95	5.40	83.17	84.56	1.39	83.39	85.58	2.19	N/A	N/A	N/A

Note: M_0 and M_1 denote means pre- and post-occupancy, respectively. $\Delta M = M_1 - M_0$.

Table A.6
Results of descriptive statistical analysis of occupant perceived well-being in the six companies pre-versus post-occupancy.

	Company A			Company B			Company C			Company D			Company E			Company F		
Parameter	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM	M_0	M_1	ΔM
The workplace makes me …																		
energized.	−0.14	0.91	1.05	−0.32	1.05	1.37	0.21	0.76	0.55	0.11	0.56	0.45	0.29	1.03	0.73	0.13	0.85	0.73
motivated to work.	0.11	1.16	1.04	−0.05	0.79	0.83	0.64	0.75	0.11	0.58	0.95	0.37	0.79	1.14	0.35	0.59	1.01	0.43
excited about coming to work.	0.60	1.00	0.40	−0.27	1.00	1.27	0.61	0.76	0.16	0.55	0.90	0.35	0.81	1.08	0.27	0.58	1.01	0.44
*wish I worked in another building.	−0.40	1.34	1.74	−0.73	1.58	2.31	−0.76	1.41	2.17	0.31	0.35	0.04	−0.31	1.10	1.41	0.17	1.19	1.02
proud to be a part of this organization.	−0.18	1.41	1.59	−0.18	1.32	1.50	0.48	1.22	0.73	0.66	1.17	0.51	0.57	1.51	0.93	0.45	1.29	0.84
The workplace supports my …																		
thinking and analytical work.	−0.17	0.81	0.98	−0.45	0.89	1.35	0.30	0.90	0.60	0.36	0.68	0.32	0.53	1.03	0.49	0.47	0.87	0.40
ability to retreat and have private conversations.	−1.29	1.50	2.79	−0.68	1.16	1.84	−1.30	0.82	2.13	−0.09	0.24	0.32	−0.07	1.01	1.08	0.08	1.23	1.15
The workplace …																		
is conducive to my health and well-being.	−0.26	1.13	1.38	−0.18	1.37	1.55	0.21	0.94	0.73	−0.06	0.61	0.68	0.44	1.11	0.67	0.25	0.96	0.71
facilitates collaborative working.	0.38	1.59	1.21	0.19	1.53	1.34	0.67	1.02	0.35	0.47	0.93	0.47	0.51	1.36	0.85	0.60	1.28	0.68
helps to have chance meetings.	0.12	1.28	1.16	−0.05	1.22	1.27	0.55	0.86	0.31	0.16	0.65	0.48	0.24	1.20	0.96	0.32	0.99	0.67
The organization cares about how …																		
the physical work environment impacts mental health.	−0.21	1.06	1.27	0.76	1.47	0.71	0.76	0.86	0.10	0.11	0.94	0.83	0.57	1.25	0.68	0.41	1.19	0.78
Average ΔM	1.33			1.39			0.72			0.44			0.77			0.71		

Note: M_0 and M_1 denote means pre- and post-occupancy, respectively; $\Delta M = M_1 - M_0$; *Responses have been reverse coded.

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