University Library

A gateway to Melbourne's research publications

Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:
Candido, C;Marzban, S;Haddad, S;Mackey, M;Loder, A

Title:
Designing healthy workspaces: results from Australian certified open-plan offices

Date:
2020

Citation:
Candido, C., Marzban, S., Haddad, S., Mackey, M. & Loder, A. (2020). Designing healthy workspaces: results from Australian certified open-plan offices. Facilities, 39 (5-6), pp.411-433. https://doi.org/10.1108/F-02-2020-0018.

Persistent Link:
https://hdl.handle.net/11343/267997

Designing healthy workspaces: results from Australian certified open-plan offices

Abstract

Purpose – From poor Indoor Environmental Quality (IEQ) conditions to musculoskeletal discomfort, the interior design of workspaces has the potential to negatively affect human health. One of the key responses from industry has been the rise of health-related guidelines, certification and rating tools. Despite the rapid adoption of such tools by the Australian high-end corporate real estate, there is a scarcity of empirical evidence arising from such premises. This study compares results from certified premises against other open-plan offices in order to understand differences arising from occupants' satisfaction, perceived productivity and health.

Design/methodology/approach –1121 POE surveys conducted in nine offices were analyzed. All these premises hold a certification from the Green Building Council of Australia and two achieved a WELL rating. The analysis is performed in three parts: comparing WELL-certified (2 cases) and non-WELL certified (7 cases) offices along with comparison with a benchmark of 9,794 POE surveys from the BOSSA data base, comparing ABW (5 cases) and traditional (4 cases) offices along with comparison with BOSSA data base, qualitative study of the similar design features in all 9 offices accompanied with an in-depth analysis of the health-related issues that might have occurred because of poor ergonomic design. For the first two parts, ~~comparison with a benchmark of 9,794 POE surveys and~~ several t-tests are performed.

Findings – Highest scores for overall satisfaction, workability, perceived productivity and health were reported on WELL-rated premises. Offices incorporating active design principles outperformed others on workability, satisfaction with work area, collaboration, unwanted interruptions, perceived productivity and health. ABW environments outperformed the traditional offices on spatial comfort, thermal comfort, noise and privacy, personal control, comfort of furnishing, adjustability of the work area, and space to collaborate. People using sit-stand workstations reported spending significantly less time seated and female workers were more prone to reporting pain over the last 12 months. The best performing offices implemented active and biophilic design, prioritized overall ergonomics and different spaces designed to support a variety of work-related activities.

Originality/value – This research conducts a comparison between certified premises against other offices in terms of occupants' satisfaction, perceived productivity and health. A qualitative analysis is also conducted to investigate personal and physical environmental aspects. The way of working (ABW or traditional), implementation of active design features, self-reported musculoskeletal discomfort and physical activity were also investigated. The study has taken a holistic approach to investigate many health-related physical, environmental, and emotional aspects in certified workspaces.

Keywords: open-plan offices, active design, IEQ, musculoskeletal discomfort, productivity, certification
Paper type Research paper

Introduction

The way people work and where they work from have changed significantly over the last decades on the back of significant modifications on employer-employee relationships enabled by digital

transformation. In a world where millennials strongly embraced the motto "work is something we do, not a place we go to", businesses now face the challenge of striking the right balance between offering the flexibility of allowing people to work anywhere while at the same time creating a strong organizational culture. As a result, workspaces have been increasingly recognized as a key asset when attracting and keeping talent, and offices are a very much an integral part of business' culture and image.

This understanding comes with great investment from business in~~on~~ the quality of the physical configuration of offices and what is now called workplace experience, with tenants paying top dollar for ways to differentiate themselves from the competitors~~tion~~. Workers' health and wellbeing are front and center to business and workers' alike. Not surprisingly, the corporate real estate market has been increasingly embracing certification and rating schemes on the promise that their premises are superior in terms of the quality provided to workers. From the physical configuration perspective, corporate open-plan offices are now designed not only to support knowledge workers to develop their daily activities but also to improve their workplace experience and wellbeing with many seeking guidance and endorsement from health-related guidelines, certification and rating tools. For example, in 2017 the Green Building Council of Australia indicated that 35% of the workspaces in Australia were Green Star rated (Green Building Council of Australia, 2017). NABERS, in their 2017/18 annual report, mentioned a three-fold increase in the number of high-rated office building compared to the past five years (NABERS, 2018). Tools designed to link the built environment and human health are on the rise such as the WELL Building Standard (International Well Building Institute, 2014), FitWell (Center for Active Design, 2019), Healthy Active by Design (Heart Foundation, 2018), etc. Overall, these tools attempt to link human health to three key dimensions: physical, environmental and emotional/cognitive.

From the physical dimension, findings from research suggest that workspaces have the potential to positively affect occupants' incidental physical activity and overall musculoskeletal comfort by enabling them to move more frequently (Robertson and O'Neill, 2003; Candido et al., 2019.a) and providing them with adequate ergonomics (Robertson and O'Neill, 2003). Within this dimension, the design of workspaces has been recognized as a significant asset. Through the logic of active design, as a relatively new concept that addresses features of the built environment proven to support daily physical activity, spaces can be configured to prompt more movement by creating opportunities for daily physical activity, reduced sitting time and increase standing time (Engelen et al., 2017). Recommendations are targeted at the implementation and use of staircases, attractive walking routes and overall interior design of spaces. Still within the physical dimension, research findings point to the benefits of reducing sedentary behavior (Parry and Straker, 2013) and postural changes (Baker et al, 2018; Waongenngarm, Areerak & Janwantanakui, 2018). The way people work is also relevant to this dimension as research has documented the benefits of the implementation of Activity Based Working (ABW) (Candido et al., 2019.a; Rolfö et al., 2018; Budie et al., 2019). Under this way of working, workers are required to find a spot within the office that matches their task at hand thereby prompting people to move more frequently and reducing the overall time they spend seated (Foley, et al., 2016). In a research on an ABW environment by Haapakangas et al. (2018), increased workspace switching was associated with higher productivity, while an increase in self-reported time spent searching for a workspace was associated with lower productivity and well-being. When comparing ABW case studies with high satisfaction and low satisfaction scores, the main differences regard employee satisfaction with the interior design, level of openness, subdivision of space, number and diversity of workplaces and accessibility of the building (Brunia et al., 2016). The evidence indicates that implementing ABW as the way of working is not sufficient for occupants' satisfaction. The interior design plays a crucial role beyond the way of working in workspaces.

The type of available food and quality of water are also relevant to the physical dimension as it has the potential to positively impact nourishment and hydration (International Well Building Institute, 2014). In addition, some tools push further to also include specific credits and/or recommendations for the implementation of strategies, programs and policies by the organization to support physical health (International Well Building Institute, 2014). This in turn has prompted the

Facilities

implementation of end-of-trip facilities (spaces that support occupants using non-motorized ways to travel to work including secure bicycle racks, lockers and change rooms), gyms and other spaces designed to host physical activities in situ (Bellicha et al., 2015) but also the understanding that this infrastructure is needed for health promotion (Heesch and Sahlqvist, 2013). Furthermore, connections need to be made between physical infrastructure and prompts such as making the healthy choice the easy choice.

Studies have investigated the effects of the indoor environment on musculoskeletal discomfort and physical activity. Engelen et al. (2016) indicate that participants spent less work time sitting and more time standing after relocating to a new active design building. Similarly, Foley et al. (2016) reported 14% less sitting time, 11% more standing time and 3% more walking time when workers moved to a work environment designed to support ABW. In addition, the effects of ergonomic design features such as sit-stand desks on occupants' overall satisfaction and health are also explored in the recent studies. Chau et al. (2016) found a decrease in sitting time and an increase in standing time in a study on the effects of sit-stand desks on productivity and physical activity while productivity did not show any significant changes.

From the environmental dimension, Indoor Environmental Quality (IEQ) has been linked to occupants' satisfaction (Kim and de Dear, 2012), perceived productivity (Akimoto et al., 2010) and health (Asoio et al., 2020). This includes thermal comfort, lighting, acoustics and Indoor Air Quality (IAQ) conditions occupants are exposed to at their workplace. Within the context of open-plan offices, research findings have shown the negative effects of noise distraction and lack of visual privacy (Brand and Smith, 2005, Bodin Danielsson and Bodin, 2009), poor IAQ (Huizenga et al., 2006), and lack of access to daylight (Yildirim et al., 2007). In addition, research has also shown that in high performance workspaces, critical predictors for occupants' satisfaction are spatial comfort of the work area, indoor air quality, noise distraction and privacy, personal control, connection to the outdoor environment and building image and maintenance (Gocer et al., 2019; Kim et al., 2016; Akimoto, et al., 2010; Sundstrom et al., 1994; Lee and Brand, 2008; Danielsson and Bodin, 2009). The evidence points to the importance of carefully designing offices to provide occupants with enough zones that support the whole spectrum of work-related activities, from concentration to collaboration (Candido et al, 2019; Venetjoki et al., 2006). The way of working is also relevant to this as it may prompt workers to find zones within their workspace that best suit their needs during the day, depending at their activity. Recent findings support this and showed occupants from offices designed to support ABW reporting higher levels of satisfaction with IEQ conditions (Candido et al., 2019.b).

The emotional/cognitive dimension's scope is more comprehensive, clustering factors that may support a workplace experience and environment that reduces burn-out and stress, and positively affects mood, wellbeing, and ultimately mental health. This includes initiatives related to the enterprise culture and work arrangements, wellness programs and space-related attributes, (Bodin and Bodin, 2008; Bodin et al., 2014), such as enabling workers' access to nature and the outdoor environment. From the design perspective, research findings support the positive impact of biophilia on workers' overall satisfaction, productivity and wellbeing. (Candido et al, 2019.b)

Impact of certified offices

The academic literature on the certified offices regarding the physical, environmental, and emotional dimensions of the built environment has received attention in the recent years. Some studies reported significant improvements in certified offices regarding occupants' satisfaction and IEQ. A study by Liang et al. (2014) indicated significant differences in indoor environmental quality dimensions when comparing green-certified and conventional buildings. Similarly, the buildings which achieved a Green Mark standard were rated higher in satisfaction with indoor environmental quality and health (Lee et al., 2020). On the other hand, studies such as Altomonte et al., (2019) showed that achievement of a specific IEQ credit did not considerably increase satisfaction with the corresponding IEQ factor, They also indicated that the rating level, and the product and version under which certification had been awarded, did not affect workplace satisfaction. Overall, many

different factors in a workspace influence the occupants' perception of IEQ including physical, environmental and emotional/cognitive factors.

Although certification itself and alone cannot guarantee a good level of IEQ and satisfaction in the workspaces without considering other aspects of design, they can provide a basis for comparison. Current tools such as those led by the Green Building Council of Australia and WELL Building Standard have been promoting several targets that are meant to improve the physical, environmental and emotional dimensions of the built environment for years now. In Australia alone, premium offices targeting recommendations from are on the rise - it is estimated that 2,200 projects have been certified by GBCA and 147 under the WELL flagships. Despite the rapid adoption of such schemes by the Australian high-end corporate real estate, there is a scarcity of empirical evidence arising from such premises about their superiority when it comes to occupants' satisfaction, productivity and health. Furthermore, much of the research in this area to date has mainly taken a rudimentary quantitative/statistical approach. In contrast a more holistic approach is needed to test and analyze numerous variables affecting occupants' health and comfort, but beyond that to shed light on the qualities and design features that a simple statistical approach disregards. So far very little attention has been paid to evaluating design feature for health-promoting effects and minimal description of the studied workspaces is provided. Besides, many studies fail to introduce, and test various physical, environmental and personal factors.

This study aims to overcome these shortcomings by conducting statistical analysis combined with floor plan analysis and site visits. It –compares results from certified premises against other offices in order to understand differences arising from occupants' satisfaction, perceived productivity and health. Personal and physical environment aspects related to the health of occupants were also investigated, including the way of working (ABW and traditional), implementation of active design principles, self-reported musculoskeletal discomfort and physical activity.

For Peer Review Facilities

Materials and Methods

Post-Occupancy~~Evaluation~~ Evaluation Survey questionnaires

Results from 1121 Post-Occupancy Evaluation (POE) questionnaires collected from nine offices were analyzed for this paper. The POE questionnaire was comprised of two parts. The first part of the POE survey uses questions from the BOSSA Time-Lapse tool (Candido et al., 2016). This questionnaire was designed to explore building occupants' satisfaction on key Indoor Environmental Quality-related items, including thermal comfort, spatial comfort, indoor air quality, individual space, thermal comfort, noise distraction and privacy, visual comfort, connection to outdoor environment, building maintenance and perceived health and productivity (influence of the your work area on occupant's productivity). It also contains background questions asking about occupants' gender, age, type of work, and workspace arrangement. The BOSSA Time-Lapse POE is endorsed by the National Australian Built Environment Rating System (NABERS), Green Building Council of Australia (GBCA), New Zealand Green Building Council (NZGBC), and the WELL Building Standard. Participants rate their agreement on a seven-point scale (1 = lowest rating; 4 = neutral and 7 = highest rating). The second part of the POE questionnaire asked occupants to estimate their physical activity and musculoskeletal discomfort, activity time, pain, perceived workability and creativity. Furthermore, this questionnaire also asks occupants' height and weight, and questions to rate their agreement that physical configuration of workspace may/should increase their physical activity. Taken together, BOSSA Time-Lapse POE with the added physical activity and musculoskeletal discomfort questions enabled a holistic approach considering physical, environmental and emotional/cognitive dimensions.

Workspace layout and occupants

In addition to the POE surveys and in order to understand the physical configuration of the spaces investigated here, floor plans and fit-out information were also collected via structured site visits, observations and documentation. The basic design information about the workspaces studies is

summarized in **Table I**. The nine commercial buildings included here were constructed or undergone a major renovation (e.g. façade, HVAC systems) in the last 15 years. All buildings held an energy rating from the National Australian Built Environment Rating System (NABERS) and/or Green Star from the Green Building Council of Australia (GBCA). Two tenants were also awarded certification from the International WELL building standard. Tenants are from the property industry, government, consulting or finance sectors.

Out of the nine open-plan premises investigated here, four offices support a traditional way of working thereby workers are assigned to a desk and they perform most of their daily activities from the same location. These spaces are marked as "traditional" in **Table I**. The five other offices were designed to support ABW. Seven out of nine offices have a layout without any partitions and two adopted a mix of open-plan without partitions, high partitions and private offices. The internal configuration of offices were also analyzed in order to identify key features implemented that can be directly linked to active and biophilic design principles, including the design and location of stairs, sit-stand desk use, access to daylight, greenery and outdoor environment and views.

Occupants' background data were collected as summarized in **Table II**. The 1121 participants (49% females and 49.9% males) are mostly (63.2%) aged between 31 to 50 years old with 54.4% in the normal range for BMI. The majority of participantstes have reported working hours of more than 30 per week.

Table I: Basic information about the offices.

Way of working	N = 1,121	Fit-out	Certification	Tenant
ABW 1	90	Open-plan office without partitions	WELL Green Star (6 Star)	Property industry
Traditional 1	161	Open-plan office without partitions	WELL Green Star (5 Star)	Property industry
ABW 2	170	Open-plan office without partitions	NABERS NABERS (4.5 Star)	Government
ABW 3	85	Open-plan office without partitions	NABERS (3, 4 and 4.5 Star)	Property industry
Traditional 2	122	Open-plan office without partitions	Green Star (6 Star)	Government
ABW 4	178	Open-plan office without partitions	Green Star (5 Star)	Consulting
Traditional 3	94	Open-plan office without partitions/Private offices	Green Star (4.5 an 5 Star)	Finance
ABW 5	133	Open-plan office without partitions	Green Star(6 Satr) NABERS (4 and 5 Star)	Finance
Traditional 4	88	Open-plan office without partitions/Open plan with high partitions/ private offices	Green Star NABERS	Finance

Table II: Participant demographic information for all offices (n=1121).

Characteristic		Count ~~(N%)~~	N%
Sex	Female	549 ~~(49.0%)~~	49.0
	Male	559 ~~(49.9%)~~	49.9
	Prefer not to respond	13 ~~(1.2%)~~	1.2
Age (years)	30 years old or under	206 ~~(18.4%)~~	18.4
	31 to 50 years old	709 ~~(63.2%)~~	63.2
	Over 50 years old	189 ~~(16.9%)~~	16.9
BMI	Underweight (<18.50)	11.00 ~~(1.0%)~~	1.0
	Normal range (18.50–24.99)	609 ~~(54.4%)~~	54.4
	Overweight (25.0 – 29.99)	361 ~~(32.3%)~~	32.3
	Obese (≥30.0)	138 ~~(12.3%)~~	12.3
Hours per week in work area	10 hours or less	60 ~~(5.4%)~~	5.4
	11 to 30 hours	310 ~~(27.7%)~~	27.7
	More than 30 hours	751 ~~(67.0%)~~	67.0

Facilities

Analysis

Mean scores from occupants' survey questionnaires collected from offices investigated here were compared against the BOSSA benchmarking database in order to understand their overall performance. The BOSSA benchmarking score includes 9,794 POE surveys conducted in 77 Australian offices. Mean scores from the two WELL certified premises were isolated to be compared against the dataset of seven certified offices and BOSSA benchmarking to identify key differences in terms of performance. **Table III** represents a summary of the variables investigated and tests conducted for this study, and **Figure 1** shows a conceptual model of the health-related factors considered for this study.

Table III: Summary of design variables and the test types

Analysis heading	Variable category and type of test (layer 1)	Variable category and type of test (layer 2)	Variable category
WELL and non-WELL	IEQ (Descriptive statistics)	Spatial comfort (T-test)	Visual aesthetics Space for breaks Comfort of furnishing Adjustability of work area Space to collaborate Interaction with colleagues
		Connection to outdoor environments (T-test)	Sense of connection External view Access to daylight
	Productivity and health (Descriptive statistics)	-	-
ABW and traditional	IEQ (Descriptive statistics)	-	-
	Productivity and health (Descriptive statistics)	-	-
	Other variables (T-test)	Unwanted interruptions, Workability, Adjustability, Comfort, Satisfaction- building, Space to collaborate, Comfort of furnishing, Productivity, Health, Visual privacy, Storage, Interaction, Space for breaks (T-test)	-
WELL features	WELL Movement	Spatial comfort (T-test)	Comfort of furnishing Adjustability of work area Access to sit-stand desks
	WELL Mind	Connection to outdoor environments (T-test)	Connection to outdoor External view Access to daylight
	Personal variables (T-test and MANOVA)	Pain Sit-stand desks Physical activity	-

Facilities

Independent sample t-tests were carried out: first, to examine the effect of space and way of working; second, to explore the impact of the reported pain and; third, to examine health-related behavior. A one-way multivariate analysis of variance (MANOVA) was also carried out to examine the effect of sit-stand desk use. In this research, Cohen's d was adopted when comparing two means. It is calculated as the difference between the means divided by average of the standard deviations. In Cohen's effect size, 0.2 is considered a small effect size, 0.5 is a medium and 0.8 is a large effect size (Cohen, J., 1988). In addition to the statistical analysis, a qualitative analysis is performed to investigate the WELL-related design features in all nine offices.

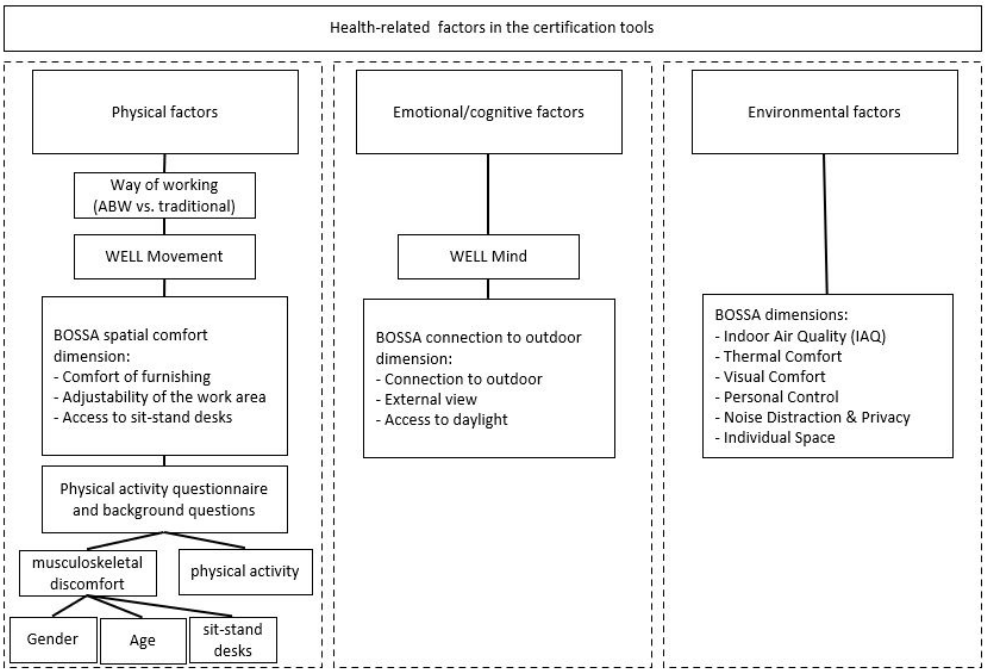

Figure 1: Conceptual model of the health-related factors considered for this study

Results

WELL certified versus non-WELL certified offices

As depicted on **Figure ~~1~~2**, on average, occupants' satisfaction scores from all offices investigated here outperformed the BOSSA benchmarking database on spatial comfort, IAQ, thermal comfort, visual comfort, connection to outdoor environment, building image and maintenance and overall performance, health and productivity. Out of the spatial configuration of offices, the strongest satisfaction scores were observed for indoor air quality, spatial comfort and visual comfort. Certified offices investigated here also outperformed the benchmarking database on the overall score for performance, perceived productivity and health (**Table IV~~III~~**).

On average, POE scores from the two WELL certified offices outperformed the rest of the dataset investigated here on all BOSSA dimensions, including overall performance, productivity and health (see **Table IV** ~~**III**~~). When compared to the benchmarking scores, occupants rated WELL-certified premises much higher (more than 0.5 score difference on a 7-point Likert scale) on overall performance, spatial comfort, IAQ, thermal comfort, connection to outdoor environment, and visual comfort compared to non-certified offices. With smaller differences (less than 0.5 score), WELL-certified offices also outperformed the database and other certified premises investigated here on personal control, noise distraction and privacy and individual space.

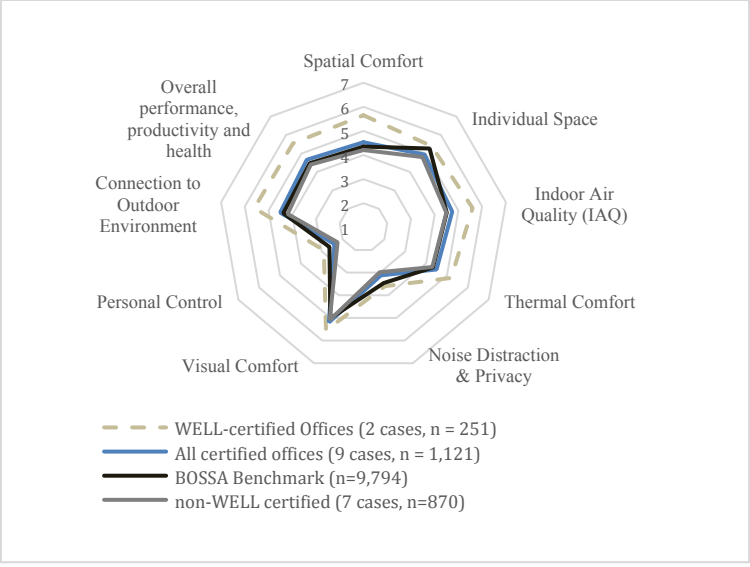

Figure ~~1~~2: POE results from open-plan, WELL, non-WELL, and all offices

~~On average, POE scores from the two WELL certified offices outperformed the rest of the dataset investigated here on all BOSSA dimensions, including overall performance, productivity and health (see **Table III**). When compared to the benchmarking scores, occupants rated WELL-certified premises much higher (more than 0.5 score difference) on overall performance, spatial comfort, IAQ, thermal comfort, connection to outdoor environment, and visual comfort compared to non-certified offices. With smaller differences (less than 0.5 score), WELL-certified offices also outperformed the database and other certified premises investigated here on personal control, noise distraction and privacy and individual space.~~

Table IV ~~III~~: Mean scores observed for all BOSSA dimensions from the benchmarking database (n= 9,794), all offices (n=1121) and WELL-certified premises. ~~Apindicatesa s.~~

Dimension	BOSSA Benchmark (n=9,794)	All offices (n = 1,121)		WELL Certified (n = 251)		**Non-WELL Certified (n=870)**	
		Mean score	Difference *	Mean score	Difference*	Mean score	Difference*
Spatial Comfort	4.35	4.53	+0.18	5.65	+1.30	4.21	-0.14
Connection to Outdoor Environment	4.38	4.51	+0.14	5.60	+1.22	4.81	-0.46
Indoor Air Quality (IAQ)	4.51	4.74	+0.24	5.60	+1.09	4.49	-0.02
Overall performance, productivity and health	4.47	4.66	+0.19	5.55	+1.08	4.30	-0.03
Thermal Comfort	4.33	4.50	+0.17	5.20	+0.87	2.98	-0.48
Visual Comfort	5.02	5.20	+0.18	5.55	+0.53	5.10	0.08
Personal Control	2.63	2.39	-0.24	2.90	+0.27	2.24	-0.39
Noise Distraction & Privacy**	3.46	3.12	-0.34	3.60	+0.14	4.20	-0.18
Individual Space	5.27	4.94	-0.33	5.40	+0.13	4.40	-0.07

**"Noise Distraction and Privacy" is the average of 4 questions on Likert 1-7 scale. The respondents state their dissatisfaction-satisfaction or disagreement-agreement on this scale.
*A positive mean difference indicates the dataset outperforms the BOSSA benchmark while a negative mean difference means the dataset underperforms the BOSSA benchmark.

Since the biggest differences in average scores were found on occupants' satisfaction on spatial comfort and connection to outdoor environment dimensions from WELL and non-WELL certified for the nine offices investigated here, all questions from this dimension were then analyzed in detail. As depicted in ~~–~~**Table V ~~Table IV~~**, significant, medium to large size differences were found for the spatial comfort dimension, namely in decreasing order - space for breaks, aesthetics, comfort of furnishing, ability to adjust the work area, space for collaboration and interaction with colleagues. As depicted in **Table III**, medium to large size association were also found for the connection to

outdoor environment dimension. For this dimension, scores were significantly different for sense of connection between indoor and outdoor environment, external view and access to daylight.

Table VI~~V~~: Effect sizes from the spatial comfort dimension for WELL (2 cases, n=251) and non-WELL certified offices (7 cases, n=870)~~(n=1121)~~.

Dimension - Spatial Comfort	Mean difference	Effect size
Visual aesthetics of work area	2.0	1.25
Space for breaks	1.9	1.12
Comfort of furnishing	1.3	0.81
Adjustability of work area	1.4	0.77
Space to collaborate	1.1	0.73
Interaction with colleagues	0.9	0.66

P<0.05 for all variables

Table III~~I~~: Effect sizes from the connection to outdoor environment dimension for WELL (2 cases, n=251) and non-WELL –certified offices (7 cases, n=870)~~(n=1121)~~.

Dimension - Connection to outdoor environment	Mean difference	Effect size
Sense of connection between normal work area and the outdoor environment	1.78	1.00
External view from normal work area	1.56	0.85
Access to daylight from normal work area	1.07	0.63

P<0.05 for all variables

Despite the fact that one WELL-certified office was designed to support Activity-Based Working and the other was a traditional office, both open-plan, WELL-certified premises incorporated a variety of spaces purposively allocated for different activities, from concentration to large-collaborative activities. Inclusion of private spaces and quiet rooms along with collaborative spaces within open-plan offices was implemented here with intention to address well-known issues such as lack of privacy and ability to concentrate while at the same time boosting innovation and creativity. Sit-stand desks and standing conference and meeting points are also in use. Adjustable workstations and chairs assessed by an ergonomist for individual ergonomic assessments are among the design feature incorporated by offices.

Offices designed to support ABW versus traditional

Since the way of working emerged as a significant factor contributing to workers' satisfaction, it was further investigated here. Average scores from POE surveys indicate that open-plan offices designed to support ABW outperformed traditional settings on spatial comfort, thermal comfort, noise distraction and privacy and personal control. Traditional offices were rated higher on average on visual comfort and connection to outdoor environment (**Figure ~~2~~3** and **Table VII**).

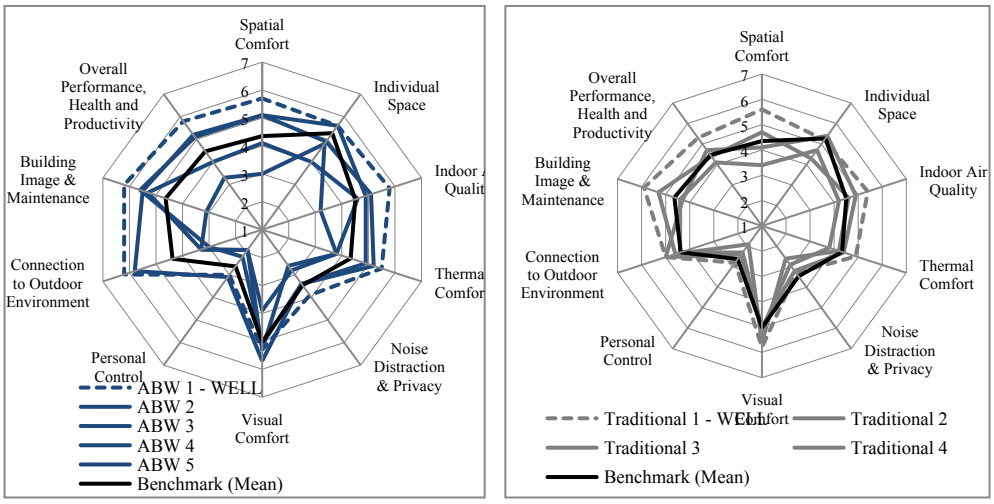

Figure ~~2~~3: POE results from open-plan offices designed to support ABW and traditional ways of working.

Table VII: Mean scores observed for all BOSSA dimensions from the benchmarking database (n= 9,794), ABW offices (5 cases, n=656) and Traditional premises (4 cases, n=465).

Dimension	BOSSA Benchmark (n=9,794)	ABW (n = 656)		Traditional (n = 465)	
		Mean score	Difference	Mean score	Difference
Spatial Comfort	4.35	4.60	0.25	4.45	0.10
Connection to Outdoor Environment	4.38	4.32	-0.06	4.75	0.37
Indoor Air Quality (IAQ)	4.51	4.72	0.21	4.78	0.27
Overall performance, productivity and health	4.47	4.68	0.21	4.63	0.16
Thermal Comfort	4.33	4.64	0.31	4.33	-0.01
Visual Comfort	5.02	5.06	0.04	5.38	0.36
Personal Control	2.63	2.42	-0.21	2.35	-0.28
Noise Distraction & Privacy	3.46	3.22	-0.24	3.00	-0.46
Individual Space	5.27	4.98	-0.29	4.90	-0.37

When it comes to satisfaction with the physical configuration of the space, medium size effects were found for satisfaction with spatial comfort, adjustability of work area, space to collaborate, comfort of furnishings and number of unwanted interruptions. ABW workspaces were also rated higher by occupants on noise and privacy and visual privacy but these were small-size effects. This could be due to integrating some design features like acoustic partitions, giving the choice to the occupant to select their work area/zone based on their tasks.

The average spatial comfort, adjustability, and the amount of personal storage have also been investigated in ABW and traditional offices. ABW exceeded traditional workspaces in average spatial comfort, and adjustability while traditional workspaces outperforms ABW in amount of personal storage (very small effect size). Workers in ABW offices also rated the collaboration space, comfort of furnishing, and unwanted interruptions significantly higher (medium effect size) compared to workers in the traditional offices. In contrast, no significant difference was found between two groups in how workers rated their interaction with other colleagues, and spaces for breaks. The mean for "interaction with colleagues" is higher in ABW workspaces, while "space for breaks" gained a slightly higher mean in traditional offices.

A separate independent sample t-test was performed to investigate statistical significance between the two WELL-certified offices. Although both offices are performing very well in terms of perceived productivity, health and satisfaction, office number 1 which integrated ABW as the way of working gained higher scores in these parameters. T-test shows that occupants have rated office number 1 significantly higher compared to office number 2 in productivity, health, creativity, overall satisfaction, and space to collaborate.

Table IVI: Independent sample t-test results.

Variable	Way of Working	Mean	Mean difference	Significance (two-tailed)	Effect size (ES)
Unwanted interruptions	ABW Traditional	3.61 3.24	0.37	0.000	0.49
Workability	ABW Traditional	7.10 6.45	1.25	0.000	0.47
Adjustability of working area based on personal preference	ABW Traditional	4.33 3.64	0.68	0.000	0.33
Satisfaction- overall comfort of work area	ABW Traditional	4.97 4.49	0.47	0.000	0.27
Satisfaction- –overall building	ABW Traditional	5.07 4.66	0.41	0.000	0.25
Space to collaborate	ABW Traditional	5.14 4.69	0.45	0.000	0.23
Comfort of furnishing	ABW Traditional	5.07 4.55	0.52	0.000	0.28
Productivity	ABW Traditional	4.72 4.35	0.36	0.000	0.20
Health	ABW Traditional	4.64 4.30	0.33	0.001	.19
Visual privacy	ABW Traditional	3.05 2.70	0.35	0.001	0.11

Storage satisfaction	ABW Traditional	4.52 4.83	0.30	0.010	0.01
Interaction with colleagues	ABW Traditional	5.14 5.03	-	Not significant	-
Space for breaks	ABW Traditional	4.15 4.23	-	Not significant	-

WELL features implemented in all nine offices

As discussed earlier, all nine offices investigated in this research hold a certification with two offices being WELL v.1 certified. WELL Building Standard is a comprehensive and robust standard well adopted in Australian market. It includes sections related to mental and physical health, IEQ, organizational relations and other parameters. For the purpose of this study, the WELL-related design features are extracted for nine certified offices. These features are introduced in **Table IX~~VIII~~**. the integration of the WELL features is not related to the fact that whether a specific office has received a WELL building certification.

Table IX~~VIII~~: Key features from WELL Movement and Mind implemented by 5-highly ranked offices.

	WELL Movement
V01	Active Buildings and Communities by promoting movement, physical activity and active living through the design of built spaces.
V02	Visual and Physical Ergonomics: Reduce physical strain and injury, improve ergonomic comfort and workplace safety and general well-being through ergonomic design
	Part 1: Monitors with built-in height adjustment, Height-adjustable stands. Mounted, adjustable arms that hold primary or additional screens.
	Part 2: For at least 25% of seated-height workstations, employees have the ability to alternate between sitting or standing through one of the following: Adjustable height sit-to-stand desks or desktop height-adjustment stands.
	Part 3: Adjustable furniture and flexible seats
V03	Movement Network and Circulation: Promote daily physical activity and movement through the design of the circulation network.
V07	Provide active workstations: provide Sit-stand workstations and dynamic workstations (treadmill desks, bicycle desks, and portable furnishing)
V08	Dedicated physical activity spaces and equipments
	WELL- Mind
M02	Access to nature through interior and exterior design
M07	Support access to restorative spaces (both indoor and outdoor) to promote relief from mental fatigue or stress.
M09	Enhanced access to nature beyond M02 by further incorporating nature through interior and exterior design, nature views and access to nearby nature.

Spatial comfort dimension is the mostly relevant dimension to the features discussed in WELL Movement. The 5 offices which are receiving the highest satisfaction rates for spatial comfort are ABW 1, ABW 2, ABW 3, Traditional 1, and Traditional 2. The floor plan analysis of the five offices revealed similarities regarding WELL v.2 features. The most predominant features regarding WELL Movement (V01 and V03) is the design of the movement network and circulation areas. The staircases are a central component of the building design, easily accessible and visible from different zones including the entrance. This setting promotes incidental physical activity for the occupants and encourages them to use the stairs instead of the lifts in multi-floor tenancies.

All (100%) of the occupants in two of the highest rated offices for spatial comfort (ABW 1 and ABW 3) have access to sit-stand desks. These offices received the highest scores by far for comfort of furnishing and adjustability of the work area (**Table ~~I~~X**). In one office (Traditional 4), 42% of the occupants have access to sit-stand desks, hence the scores for comfort of furnishing (5.06) and adjustability of the work area (4.34) are in between the offices with 100% access and no access to sit-stand desks (with the exception of Traditional 1). Clearly the design features from WELL Movement section (V02 and V07) regarding ergonomic comfort and well-being are met in these offices noting that one of these offices holds a WELL certification while the other one does not.

Connection to the outdoors dimension is comprised of features related to the WELL Mind concept. The highest rated offices regarding connection to the outdoors, external views and daylight (**Table ~~I~~X**) are ABW 1 and ABW 3 with an average of 75-100 and 50 percentage of glass for different

facades. These offices both have a view to water which can be considered as nature views (WELL Mind- M09). Although the office which has received the lowest score for connection to the outdoors, external views and daylight (ABW 2) has a high percentage of glass on its façade (average 75-100%), the view is mainly limited to close buildings and street. The two offices (ABW 1 and ABW 3) have also developed a biophilia plan that incorporates nature patterns throughout the workspace through several different varieties of plants, including indoor plants and even small trees (WELL Mind, M02. M07 and M09). Both offices clearly prioritize occupants' access to daylight.

These premises incorporated a variety of spaces purposively allocated for different work-related activities, from concentration to large-collaborative activities. Inclusion of private spaces and quiet rooms along with collaborative spaces within open-plan offices was implemented here with the intention to address well-known issues such as lack of privacy and the ability to concentrate while at the same time boosting innovation and creativity.

All five offices discussed had a combination of design features aiming at improving workers' physical and mental health that were missing in other offices investigated here. Combined, design features implemented from these offices targeted to maximize access to daylight and nature, access and use of stairs, and furniture adjustability and ergonomics.

Table IX: Scores observed for comfort of furnishing and adjustability of the work area for all 9 offices

	Traditional 1-WELL	Traditional 2	Traditional 3	Traditional 4	ABW 1-WELL	ABW 2	ABW 3	ABW 4	ABW 5
Comfort of furnishing	5.16	4.43	5.16	5.06	5.43	4.44	5.57	4.98	4.24
Adjustability of the work area	3.73	3.70	3.73	4.34	4.90	3.44	4.96	3.90	3.27
Access to sit-stand desks	Yes %)	0	42	0	0	100	100	0	0
	No (%)	100	58	100	100	0	0	100	100
Sense of connection to outdoor environment	4.83	4.70	3.26	5.19	6.47	2.54	6.08	3.20	4.60
External view	5.28	5.38	3.76	5.49	6.29	3.35	6.10	3.95	5.20
Access to daylight	5.00	3.87	2.93	4.32	5.75	3.08	5.09	2.84	3.48

For all variables, participants rated their agreement/satisfaction on a seven-point Likert scale (1 = lowest rating; 4 = neutral and 7 = highest rating)

WELL Movement and active design principles: Self-reported musculoskeletal discomfort and physical activity in offices with active design principles

Having discussed the features related to WELL Movement and its possible effect on the occupants, analysis of the personal variables related to WELL Movement follows. Certified offices investigated here were also analyzed based on the implementation of active design principles. Active design is a relative new concept that aims to exploit opportunities within built environment to improve physical health. Floorplan analysis combined with site visits enabled researchers to map the implementation of active design principles for all offices investigated here. Coincidently, offices designed to support ABW also presented the biggest number of active design strategies implemented. These offices implemented strategies focusing on stair location and visibility, stair dimensions, appealing stair environment, stair prompts, building programming, appealing and supporting walking routes along, and overall ergonomics.

Three measures of physical activities were assessed based on self-reported percentage of daily sitting, standing, and walking. The overall effect of the way of working on self-reported sedentary behaviour was not significant. Participants reported the same amount of time (average of 183 minutes) spent on walking and activities per week, and this did not change significantly for the

workers in spaces with the adoption of several active design principles and other offices. That said, the amount of reported sitting and standing times are slightly lower in active design workspaces, while the walking time is marginally higher. The percentage of self-reported sitting time is also significantly lower in WELL-certified premises.

The time spent on walking and overall self-reported physical activity increased significantly ($P<0.000$ and $P<0.032$, respectively), when participants used a health-related device or gadget. When using the health gadget, people reported an average of 224.56 minutes of walking and 202.22 minutes of doing moderate or vigorous physical activities. These times decreased to 167.33 minutes for walking and 176.37 minutes for physical activities when no health gadget was used. Regardless of the way of working, females reported to have less physical activity compared to males. The mean for "Total time spent for doing moderate or vigorous physical activity (Minutes per week)" is 155.92 for females while it is 195.73 minutes for the male occupants ($p<0.005$).

When occupants were asked if they had pain in the last 12 months, 70% answered yes (**Figure 24**). **Table I** shows significant differences in two groups of people who said 'yes' and 'no' to the self-reported musculoskeletal pain in the last 12 months. The occupants who have not reported pain are in general more satisfied with their workspace. They have reported higher productivity, health and workability (performance). They have also rated their workspaces higher in dimensions relevant to active design principles, including spatial comfort, comfort of furnishing and space for breaks. A similar trend can be seen for the self-reported pain in the last 7 days (**Table II**).

Table XI: Independent sample t-test results for two groups of people who have reported (yes) and not reported (No) pain over the last year on occupant satisfaction.

Variable	Pain last year*	Mean	Mean difference	Significance (two-tailed)	Effect size (ES)
Comfort of furnishing	Yes	4.62	0.71	0.70	0.41
	No	5.33			
Health	Yes	4.31	0.56	0.000	0.35
	No	4.88			
Satisfaction overall comfort	Yes	4.59	0.50	0.000	0.31
	No	5.10			
Productivity	Yes	4.44	0.36	0.001	0.21
	No	4.80			
Workability	Yes	6.99	0.37	0.017	0.15
	No	7.37			
Adjustability of working area based on personal preference	Yes	3.91	0.29	0.024	0.14
	No	4.21			
Average Spatial Comfort	Yes	4.41	0.45	0.000	0.31
	No	4.87			

*The question around pain is framed as "Have you at any time during the last 12 months had trouble (ache, pain, discomfort) in: Responses: Neck, right shoulder, left shoulder, both shoulders, upper back, low back, legs, feet and ankle, not applicable". The response is considered "yes" if the respondent has selected at least one pain/discomfort area.

Table VII: Independent sample t-test results for reported pain over the last week on occupant satisfaction.

Variable	Pain last year	Mean	Mean difference	Significance (two-tailed)	Effect size (ES)
Comfort of furnishing	Yes	4.52	0.63	0.000	0.37
	No	5.16			
Health	Yes	4.15	0.68	0.000	0.42
	No	4.84			
Satisfaction overall comfort	Yes	4.50	0.50	0.000	0.31
	No	5.01			
Productivity	Yes	4.32	0.47	0.000	0.27
	No	4.79			
Workability	Yes	6.84	0.54	0.000	0.22
	No	7.38			
Adjustability of working area based on personal preference	Yes	3.74	0.54	0.000	0.27
	No	4.28			

Facilities

When broken down by gender, significant differences were found in the reported pain over the last 12 months between males and female workers. As depicted in **Figure 23**, of those workers reporting pain in the last 12 months, 37.5% were female and 32.8 were male. Within the female workers with pain in the last 7 days, shoulders are the most reported areas, along with neck and upper back as the second and third most frequently reported painful areas, while for the male workers legs are the affected area with the highest percentage (**Table VII**).

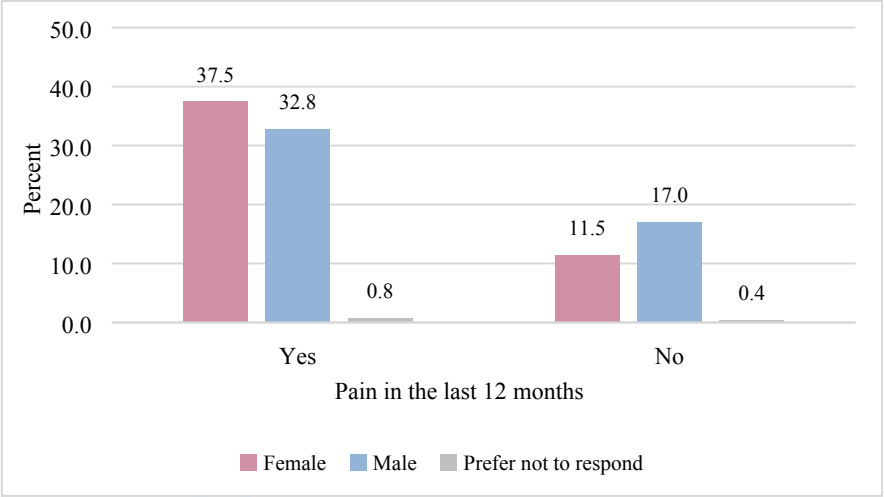

Figure 24: Reported pain results for male and female workers in the last 12 months.

Table VIII: *Gender-based reported pain areas.*

		Reported pain area (%)								
		Neck	Left shoulder	Low back	Feet and ankle	Right shoulder	Legs	Both shoulders	Upper back	Not applicable
Gender	Female	58.8	57.1	50.5	50.0	63.6	48.2	67.1	57.6	40.4
	Male	41.2	42.9	49.5	50.0	36.4	51.8	32.9	42.4	59.6

The incorporation of sit-stand workstations for all offices in this study generally overlapped with higher overall satisfaction, health, and productivity results with mostly medium to high effect sizes (**Table XIVXII**). Higher satisfaction results (medium size effects) were also found with overall satisfaction with the comfort of the work area, including adjustability of work area and comfort of furnishing. A one-way multivariate analysis of variance was run to determine the effect of using sit-stand desks on sedentary and non-sedentary physical activities. Three measures of physical activities were assessed namely self-reported percentage of daily sitting, standing, and walking with reference to the use of sit-stand desks. The difference between the two groups on the combined dependent variables was statically significant. Follow-up univariate ANOVAs showed that both self-reported sitting and standing time were significantly different between the occupants who used or did not use sit-stand desks. A lower percentage of occupants who used sit-stand desk (32%) reported prolonged seated time (76-100% of time sitting per day) compared with the percentage of occupants who did not use sit-stand desk (46%). Further, occupants who were using sit-stand desks reported significantly higher standing time. Also, no statistically significant difference was found in means of two groups with and without sit-stand desks in the self-reported pain. Among all reported pains in all investigated buildings, lower back and neck pain were the most common reported problems accounting for about 50% of all self-reported pains over the last 12 months and 7 days.

Table XIV~~XII~~: Independent sample t-test results for effect of using sit-stand desks on occupant satisfaction~~.~~

Variable	Sit-stand desks	Mean	Mean difference	Significance (two-tailed)	Effect size (ES)
Health	Yes	4.98	0.70	0.000	0.43
	No	4.27			
Productivity	Yes	5.00	0.64	0.000	0.38
	No	4.36			
Satisfaction overall comfort	Yes	5.28	0.76	0.000	0.48
	No	4.52			
Adjustability of working area based on personal preference	Yes	4.89	1.24	0.000	0.63
	No	3.64			
Comfort of furnishing	Yes	5.57	1.04	0.000	0.64
	No	4.53			

P<0.05 for all variables

Discussion

Literature has been catching up on providing a fast-paced industry with evidence-based research concerning certified premises. This research has ~~focussed~~focused on the advantage of certified premises on the perception of physical environment, satisfaction, performance and health. ~~This paper focuses on~~ It presented a comparison of Post-Occupancy Evaluation surveys results from Australian, high-end certified premises against other open-plan offices in order to understand differences arising from occupants' satisfaction, perceived productivity and health. The way of working, implementation of active design features, self-reported musculoskeletal discomfort and physical activity were also investigated. The study has taken a holistic approach not only in investigating environmental, physical and personal factors related to health, but also in testing and analyzing many different variables related to these factors. It is one of the first to qualitatively investigate WELL related design features in different case studies and enrich the qualitative analysis by statistically testing the health-related variables.

The findings of this study show that nine certified offices in this study outperformed the BOSSA benchmark in the majority of the IEQ dimension including spatial comfort, IAQ, thermal comfort, visual comfort, connection to the outdoor environment, building image and maintenance and overall performance, health and productivity. These nine offices also received higher scores for performance, perceived productivity and health when compared with BOSSA benchmark. These finding are aligned with the finding of a study by Liang et al. (2014) which reported significant improvements in indoor environmental quality dimensions when comparing green-certified and conventional buildings. Similar findings are reported by Lee et al. (2020) regarding the higher satisfaction levels in certified building, and Mallawaarachchi and De Silva (2017) regarding higher occupants' productivity in green-certified office buildings. These findings are contradictory with studies such as Altomonte et al., (2019) which showed achievement of an IEQ certification would not necessarily mean higher occupants' satisfaction for that specific IEQ dimension.

The findings also suggest that open-plan offices designed to support ABW outperformed traditional settings on spatial comfort, thermal comfort, noise distraction and privacy, personal control, spatial comfort, adjustability of work area, space to collaborate, comfort of furnishings, number of unwanted interruptions, and visual privacy. These finding are in general aligned with the current literature on ABW environments. Candido et al. (2019) indicated that ABW workspaces yielded significantly higher satisfaction results on thermal comfort and acoustics (sound privacy, interruptions and noise overall). Ekstrand and Damman (2016) reported that having separate zones provide more opportunities for the employees to handle work demands and perceived control. Satisfaction with the furniture in ABW environments is pointed out by Lusa et al. (2019), while the contradictory findings of dissatisfaction with acoustics is mentioned by the same study. Regarding ease of collaboration in the ABW environments, the findings of this study are in line with a study by Arundell et al. (2018) which reported a positive association between ABW offices and collaboration opportunities. In contrast, a study by Wohlers et al. (2018) suggested negative effects

of an ABW environment on communication and collaboration among team members, while improvements were observed in the inter-team collaboration.

Traditional offices were found to exceed ABW environments in the amount of personal storage, visual comfort and connection to the outdoor environment. Similarly, in a study by Wadu Mesthrige and Chiang (2019), lack of storage space is reported as a negative aspect of ABW environments. They reported that this aspect negatively influenced workers' productivity. Furthermore, connection to the outdoor environment was rated higher in ABW environments in line with a previous study by Candido et al. (2019a).

The incorporation of sit-stand workstations for all offices in this study coincided with higher overall satisfaction, health, and productivity results with mostly medium to high effect sizes. People using sit-stand workstation also reported spending significantly less time seated. Participants' self-reported sitting time decreased and standing time increased when they worked in spaces with sit-stand desks. These finding are aligned with as a study by Chau et al. (2016) which reported a decrease in sitting time and an increase in the standing time when using sit-stand desks in an office environment. Engelen et al. (2016) and Foley et al. (2016) also reported similar results when occupants used active design furniture in ABW environments.

Female workers were more likely to reporting feeling pain over the last 12 months. Lower back and neck pain were common problem reported by the participants in all investigated offices. Occupants who have not reported pain over the last 12 months reported higher productivity, health and workability. They have also rated their workspaces higher in spatial comfort, comfort of furnishing and space for breaks.

This study also analyzed and reported scores for the highly ranked offices on spatial comfort and connection to outdoor environment. These two dimensions are related to WELL-Movement and WELL-Mind. Further investigation revealed similarities between all these offices regarding the interior design features that promote health-related behaviors.

For Peer Review

Limitations and future research

One of the limitations of this study is a relatively small sample size (n=1121). ~~However, it~~It should also be noted that the data utilized for this research is from POE surveys conducted in nine different offices, considering that there might be several offices within a building. Although each of these offices are unique in their features compared to other offices in this study, the authors have tried to group the results based on their most critical similarities (ABW and traditional, WELL and non-WELL). The similarities significantly affect the offices' performance. After this comparison, a qualitative analysis of the key design features was conducted to go beyond certification. Considerably more work needs to be done to analyze similarities and differences in the design features that affect the performance of a workspace.

The comparison between WELL and non-WELL certified offices is based on two WELL-certified cases. These two offices account for around one fourth of the respondents for POE surveys. One of these cases is an ABW environment while the other one is a traditional open plan office. The fact that the two WELL-certified offices are different in their way of working add some limitations to the findings of this study. Statistical tests returned significant results when WELL-certified offices compared to non-WELL certified offices, however it should be noted that these two offices should be treated as case studies. The study can be repeated using a larger sample size for WELL-certified offices to test the reliability of the findings in this research.

When considering an office environment, there are so many design elements/variables that affect occupants' satisfaction. The authors were not able to isolate specific office design features/dimensions that could predict the satisfaction results. Any relationship reported in the statistical tests is the statistical associations of the variables in this study, without being able to indicate a cause-and-effect relation between the variables.

Although activity-based offices are becoming more common~~; however~~, their design features are rarely evaluated for health-promoting effects. This study was limited to the use of self-reported measures. Larger studies with more activity-based buildings and objective measures (e.g. physical

activity level) are required to investigate health related effects of active design buildings. In addition, m~~M~~ore research needs to be conducted on active design features in certified and non-certified offices. WELL building standard, as a certification that is gaining popularity in Australia, can be used as a great guideline for different aspects of the indoor built environment. However, the way each office and activity zones are designed and linked should be regarded aligned with organizational culture.

Although this study tried to fill the gap of having a more holistic approach by testing and analyzing many different health-related environmental, physical and emotional/cognitive variables, more work will need to be done to thoroughly understand the role of these factors in the health-related outcomes

Conclusion

Combined, results from the offices investigated here suggest that targets set by tools such as the Green Building Council of Australia and WELL may have a positive effect on workers' perception of their physical environment, satisfaction, productivity and health. High performance, certified offices presented an interior design configuration that embraced the preferred way of working and a variety of spaces to support several work-related activities.

Beyond being certified or not, all offices with higher level of occupants' satisfaction for spatial comfort and connection to the outdoor environment share common design features. They implemented active design features, namely stair location and visibility, stair dimensions, appealing stair environment, stair prompts, building programming, supporting walking routes and overall ergonomics. These spaces also prioritized access to daylight and greenery. The design features documented in the WELL Building standard provide a reliable source of evidence and guidance.

Practical Implications ~~and future research~~

The findings could be practically applied as evidence to strengthen the arguments on design features of the built environment that affect occupants' satisfaction, productivity, and health. The result suggest that organization should consider the integration of active design features like staircases, sit-stand desks and adjustable furniture as critical aspects to encourage and maintain more physical activity. Tools such as WELL building standard and Green Building Council of Australia can be used as guidelines for gaining higher satisfaction, productivity and health rates. However, beyond being certified or not high-ranked offices share common design features that should be regarded in the planning phase of the office design.

~~More research needs to be conducted on active design features in certified and non-certified offices. WELL building standard, as a certification that is gaining popularity in Australia, can be used as a great guideline for different aspects of the indoor built environment. However, the way each office and activity zones are designed and linked should be regarded aligned with organizational culture.~~

Funding:

Acknowledgments: Authors would like to express their gratitude to all organizations and occupants for dedicating their time to participate in this study.

References

Akimoto, T., Tanabeb Sh., Yanaic, T., Sasakic, M. (2010) "Thermal comfort and productivity - Evaluation of workplace environment in a task conditioned office", *Building and Environment*, Vol. 45, Issue 1, pp. 45-50.

Altomonte, S., Schiavon, S., Kent, M.G. Brager, G. (2019) "Indoor environmental quality and occupant satisfaction in green-certified buildings", *Building Research and Information,* Vol. 47, Issue 3, pp. 255-274.

Arundell L., Sudholz B., Teychenne M., Salmon J., Hayward B., Healy G.N., Timperio A. (2018). "The impact of activity based working (ABW) on workplace activity, eating behaviours, productivity, and satisfaction", *Int J Environ Res Public Health,* 17;15(5):1005.

Asojo, A.O., Bae, S., Martin, C.S. (2020) "Post-occupancy Evaluation Study of the Impact of Daylighting and Electric Lighting in the Workplace", *Journal of Illuminating Engineering Society of North America, Vol. 16, Issue 3.*

Baker, R., Coenen, P., Howie, E., Williamson, A. & Straker, L. 2018, "The short term musculoskeletal and cognitive effects of prolonged sitting during office computer work", *International Journal of Environmental Research and Public Health*, vol. 15, no. 8.

Bellicha A, Kieusseian Al, Fontvieille AM, Tataranni A, Charreire Hln, Oppert JM. (2015), "Stair-use interventions in worksites and public settings - A systematic review of effectiveness and external validity". *Preventive medicine*. 2015;70:3-13. doi:10.1016/j.ypmed.2014.11.001

Bodin Danielsson, C., & Bodin, L. (2008) "Office type in relation to health, well-being, and job satisfaction among employees*", Environment and Behavior*, Vol. 40(5), pp.636–668.

Bodin Danielsson, C. and Bodin L. (2009) "Difference in satisfaction with office environment among employees in different office types", Journal of Architectural and Planning Research, Vol. 26 No. 3, pp. 241-257

Bodin Danielsson, C., Chungkham, H. S., Wulff, C., & Westerlund, H. (2014) "Office design's impact on sick leave rates", *Ergonomics*, Vol. 57(2), pp. 139–147.

Brand, J.L. and Smith, T.J., (2005) "Effects of reducing enclosure on perceptions of occupancy quality, job satisfaction, and job performance in open-plan offices", *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting*, Vol. 49, pp. 818-822

Budie B., Appel-Meulenbroek R., Kemperman A., Weijs-Perree M. (2019) "Employee satisfaction with the physical work environment: The importance of a need based approach", *International Journal of Strategic Property Management*, 23(1), pp. 36-49.

Brunia, S., De Been, I. & Van der Voordt, T.J.M.(2016) Accommodating new ways of working. Lessons from best practices and worst cases. Journal of Corporate Real Estate 18(1), 30-47.

DOI: https://protect-au.mimecast.com/s/qq0GCNLJyQUwPwvLSm84uu?domain=dx.doi.org

Candido, C. M., Kim, J., de Dear, R., and Thomas, L. (2016) "BOSSA: A multidimensional Post-Occupancy Evaluation tool", Building Research and Information, Vol.44 No. 2, pp. 214-228.

Candido, C., Thomas, L., Haddad, S., Zhang, F., Mackey, M., Ye, W. (2019.a), "Designing activity-based workspaces: satisfaction, productivity and physical activity", *Building Research & Information*, Vol. 47 Issue 3, pp. 275-289.

Candido, C., Chakraborty P., Tjondronegoro D. (2019.b) "The Rise of Office Design in High-Performance, Open-Plan Environments", *Buildings*, Vol. 9 No. 4.

Center for Active Design. (2019), "Fitwel", New York (NY), Available from: https://fitwel.org/ Google Scholar (accessed 20 June 2019).

Chau, J. Y., Sukala, W., Fedel, K., Do, A., Engelen, L., Kingham, M.,Bauman, A. E. (2016). "More standing and just as productive: Effects of a sit–stand desk intervention on call center workers' sitting, standing, and productivity at work in the opt to stand pilot study". *Preventive Medicine Reports*, 3, 68–74. doi:10.1016/j.pmedr.2015.12.003.

Cohen, J. (1988), Statistical Power Analysis for the Behavioural Sciences, 2nd ed, *Lawrence Erlbaum Associates*, New York, USA.

Ekstrand M., Damman S. (2016) "ront and backstage in the workplace: An explorative case study on activity based working and employee perceptions of control over work-related demands", *Journal of Facilities Management,* Vol. 14(2).

Engelen, L., Chau, J., Bohn-Goldbaum, E., Young, S., Hespe, D., Bauman, A. (2017) "Is Active Design changing the workplace? - A natural pre-post experiment looking at health behaviour and workplace perceptions", *Work*, Vol. 56(2), pp. 229-237.

Engelen, L., Dhillon, H. M., Chau, J. Y., Hespe, D., & Bauman, A. E. (2016). "Do active design buildings change health behaviour and workplace perceptions?" *Occupational Medicine*, 66(5), 408–411. doi:10.1093/occmed/kqv213

Foley, B., Engelen, L., Gale, J., Bauman, A., Mackey, M., (2016) "Sedentary Behavior and Musculoskeletal Discomfort Are Reduced When Office Workers Trial an Activity-Based Work

Environment", *Journal of Occupational and Environmental Medicine*, : Vol. 58 Issue 9, pp. 924-931

Göçer, Ö., Candido, C., Thomas, L., and Göçer, K. (2019) "Differences in Occupants' Satisfaction and Perceived Productivity in High-and Low-Performance Offices", *Buildings* Vol. 9 (9), p.199.

Green Building Council of Australia. (2017), "Industry leaders shine with Green Star ratings in 2017", available at: https://new.gbca.org.au/news/gbca-media-releases/industry-leaders-shine-green-star-ratings-2017/ (accessed 1 May 2020).

Haapakangas, A., Hallman, D. M. , Mathiassen, S. E., Jahncke, H. (2018), "Self-rated productivity and employee well-being in activity-based offices: The role of environmental perceptions and workspace use", *Building and Environment*, Volume 145,pp. 115-124.Heart Foundation. (2018), "Health Active by Design Master Checklist", available at: http://www.healthyactivebydesign.com.au/images/uploads/Partners/Resources/Healthy_Active_by_Design_master_checklist.pdf (accessed 20 June 2019).

Heesch, K.C. & Sahlqvist, S. 2013, "Key influences on motivations for utility cycling (cycling for transport to and from places)", *Health Promotion Journal of Australia*, vol. 24, no. 3, pp. 227-233.

Hoendervanger J.G., De Been I., Van Yperen N.W., Mobach M.P., Albers C.J. (2016), "Flexibility in use: Switching behaviour and satisfaction in activity-based work environments", *Journal of Corporate Real Estate* 18(1), pp. 48-62

Huizenga, C., Abbaszadeh, S., Zagreus, L., Arens, E. A. (2006), "Air quality and thermal comfort in office buildings: Results of a large indoor environmental quality survey", in *Journal of Environmental Psychology* 2006 proceeding of Healthy Buildings in Lisbon, Portugal, June 2006, vol. 3, pp. 393–397.

International Well Building Institute (IWBI) (2015) "The WELL Building Standard", Washington (DC) ,available at: https://www.wellcertified.com/well Google Scholar (accessed 20 June 2019).

Kim, J., Candido, C., Thomas, L., de Dear, R., (2016), "Desk ownership in the workplace: The effect of non-territorial working on employee workplace satisfaction, perceived productivity and health", *Building and Environment*, Vol. 103, pp. 203-214.

Kim, J., de Dear, R. (2012) "Nonlinear relationships between individual IEQ factors and overall workspace satisfaction", Building and Environment, Vol. 49, pp. 33-40

Konis, K. (2013), "Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office building in San Francisco", *California. Build. Environ*, Vol. 59, pp. 662–677

Lee, S., and Brand J.L. (2010) "Can personal control over the physical environment ease distractions in office workplaces?", *Ergonomics*, Vol. 53 Issue 3, pp. 324-335.

Lee, J.-Y., Wargocki, P., Chan, Y.-H.d, Chen, L., Tham, K.-W. (2020) "How does indoor environmental quality in green refurbished office buildings compare with the one in new certified buildings?", *Building and Environment*, Vol. 171, 15 March 2020, Article number 106677

Liang, H.-H., Chen, C.-P., Hwang, R.-L., Shih, W.-M., Lo, S.-C., Liao, H.-Y. (2014) "Satisfaction of occupants toward indoor environment quality of certified green office buildings in Taiwan", *Building and Environment*, Vol. 72, pp. 232-242.

Mallawaarachchi, H., De Silva, L., Rameezdeen, R. (2017). "Modelling the relationship between green built environment and occupants' productivity", *Facilities,* Vol. 35, Issue 3-4, pp. 170-187.

NABERS. (2018). "NABERS annual report 2017/18". Available at: https://nabers.info/annual-report/2017-2018/ (accessed 1 May 2020)

Parry, Sh. and Straker L. (2013), "The contribution of office work to sedentary behavior associated risk", *BMC Public Health*, Vol. 13, Article number: 296.

Robertson, M. M., and and O'Neill, M. J. (2003), "Reducing Musculoskeletal Discomfort: Effects of an Office Ergonomics Workplace and Training Intervention", *International Journal of Occupational Safety and Ergonomics*, Vol 9 Issue 4, pp. 491-502

Rolfö, L., Eklund, J., and Jahncke H. (2018), "Perceptions of performance and satisfaction after relocation to an activity-based", *Ergonomics*, 61:5.

Wilkinson, L., and Task Force on Statistical Inference, American Psychological Association, Science Directorate. (1999), "Statistical methods in psychology journals: Guidelines and explanations" *American Psychologist*, Vol 54 No. 8, p. 594-604.

For Peer Review

Yildirima, K., Akalin-Baskaya, A., and Celebi M., (2007), "The effects of window proximity, partition height, and gender on perceptions of open-plan offices", *Journal of Environmental Psychology*, Vol. 27, pp. 154–165.

Venetjoki, N., Kaarlela-Tuomaala, A., Keskinen, E., Hongisto, V. (2006) "The effect of speech and speech intelligibility on task performance", *Ergonomics*, Vol. 49, pp. 1068–1091.

Wadu Mesthrige J., Chiang Y.H. (2019) "The impact of new working practices on employee productivity: The first exploratory study in Asia", *Journal of Facilities Management*, Vol. 17, Issue 2.

Waongenngarm, P., Areerak, K. & Janwantanakul, P. 2018, "The effects of breaks on low back pain, discomfort, and work productivity in office workers: A systematic review of randomized and non-randomized controlled trials", *Applied Ergonomics*, vol. 68, pp. 230-239.

Facilities