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# Impact of workspace layout on occupant satisfaction, perceived health and productivity

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## Abstract

Open-plan layouts have evolved significantly over the last decades with innovative concepts such as Activity-Based Working (ABW) becoming the norm in workspace layout. ABW by definition requires the creation of a variety of spaces for the occupants to select from, depending on requirements of the task at hand. While much research has been done in documenting the impacts of conventional open-plan layouts. Given the hyperbole around ABW coming from the industry, it is surprising that so little empirical research conducted in ABW has been performed to date. This paper aims to contribute to this knowledge gap by examining the impact of different workspace layouts on occupants' overall satisfaction on key IEQ dimensions, perceived productivity and perceived health. Post-occupancy evaluation results from 5,171 building occupants in 30 buildings from the Building Occupant Survey System Australia – BOSSA – database were used for this analysis. Floor plans were analysed and classified into three broad categories: Hive, ABW and Cell. Results indicated that occupants in ABW layouts were generally more satisfied with IEQ issues, such as space for breaks, interaction with colleagues, space to collaborate, air quality and building aesthetics, compared to those in Hive or Cell layouts. ABW was also in association with higher occupant satisfaction than the other two spatial configurations in terms of overall work area comfort and the overall building satisfaction. Not surprisingly, Cell layouts were more successful in producing higher satisfaction scores on sound privacy and visual privacy.

Keywords: Post-Occupancy Evaluation (POE), Indoor Environmental Quality (IEQ), Activity-Based Working (ABW), perceived productivity and health.

## 1 Introduction

The expression 'the new office' has been around since early 70s however it was only around mid-90s that a revolution towards flexible ways of working has been observed and its implications documented by researchers (Harrison et al., 2004; Joroff et al., 2003; Kampschroer and Heerwagen, 2005; Vischer, 2005, 2007; Stegmeier, 2008; van Meel, 2010; De Paoli et al, 2013). Open plan working has evolved alongside with changing trends observed in business management, including, the introduction of information and communication technologies and more flexible ways of organizing work processes (De Croon et al, 2005; De Been and Beijer, 2014; Miller, 2014). Several typologies in workplace design have been observed since (Becker, 1999; van Meel and Vos, 2001; Danielsson and Bodin, 2009; Duffy, 1997; Van Meel et al., 2010). Broadly these are grouped into cellular offices (Cell) or private workspaces for no more than one or two occupants and traditional

open plan layouts where a large number of workstations are co-located in a large office floor plate (Hive).

Activity-based working (ABW) is part of the latest wave of innovative workplace design and it has been the hot trend in Spatial Planning in recent years. ABW is a concept that requires the workspace layout to be designed to accommodate a variety or work-related activities. ABW expands the boundaries from the individual workstation to the entire office footprint by allowing workers to gravitate towards the best spot to develop the task in hand - it will provide workers with team desks, quiet concentration rooms, a variety of meeting rooms, brainstorm areas, multi media rooms and lounges, resulting in environments that have little or no resemblance at all to the traditional open-plan office as we know.

While a considerable body of research has been consolidated focusing on open plans offices, most of them reporting results from Post-Occupancy Evaluation (POE) surveys in open-plan offices (Visher, 1989; Cohen et al, 2001; Vischer, 2004; Zagreus et al, 2004; Leaman and Bordass, 2007; Loftness et al. 2009; Kim and de Dear, 2012; Candido et al, 2015), the same cannot be said about ABW. Likewise detailed studies providing much needed information about Indoor Environmental Quality (IEQ) (Visher, 1989; Vischer, 2008; Jarvis 2009; Loftness et al. 2009; Mui et al, 2009; Wong and Mui, 2009; Ncube and Riffat, 2012; Cao et al, 2012; Heinzerling et al, 2013; Deuble and de Dear, 2014; Kim et al, 2012; Kim and de Dear, 2013), productivity and performance (Leaman and Bordass, 1999, 2001; De Croon et al, 2005; Perettin and Schiavon, 2011; Frontczak et al, 2012; Liang et al, 2014; Thatcher and Milner, 2014; Hartkopf, Loftness and Mill 1986; Vischer 2008; Jarvis 2009; Heinzerling et al, 2013), health (Abraham and Greham-Rowe, 2009; Smith et al, 2013; Buckley et al, 2015; Graves et al, 2015; Marmot and Ucci, 2015) and other topics related to space planning (Duffy, 1997; Fawcet and Rigby, 2009; Oksanen and Stahle, 2013) remain focused on open plan settings.

Despite the fact that at least 10 million Australians spend most of their time at their workplace and the number of conventional open-plan offices being converted into ABW in this country, findings arising from research projects developed in such environments are in very need. The main mega-drivers behind the rapid incorporation of ABW are the ability to support business growth and objectives, brand differentiation and drives in talent attraction and retention. The introduction of ABW and shared workstations enables organizations to save office space, reduce general and technical services costs and increase flexibility of office use which when combined can serve to address the sustainability agenda of the business by saving energy in Heating Ventilation and Air-Conditioned (HVAC) systems and overall carbon foot-print of the building.

Apart from the obvious financial benefits from introducing ABW, advocates also claim that the resultant workspace is able to have significant, positive impacts on any organization's most precious asset – their workers. Significant gains in productivity, health and overall satisfaction, along with the ability of ABW spaces to increase collaboration and address intergenerational needs have all been reported by industry (sometimes backed up by case studies) when describing the advantages of ABW over conventional open plan counterparts. However, empirical evidence coming from research studies in ABW settings, particularly databases that may or may not corroborate the hyperbole observed in industry is scarce (De Paoli et al, 2013; Miller, 2014; De Been and Beijer, 2014; Remoy and van der Voordt, 2014).

This paper aims to contribute to this knowledge gap by providing empirical evidence of ABW performance. A comparative analysis of the impact of different workspace layouts (Hive, ABW and Cell) on occupant satisfaction in key IEQ dimensions, perceived productivity and health was carried out. By employing the effect size measurement, this study is able to tell how important these differences really are to the real practice, thus can provide references and guidance for future architectural designs and retrofits, from the perspective of promoting building occupant satisfaction.

## 2 Methodology

### 2.1 The BOSSA project

Since 2011 the BOSSA project has been developing and implementing research tools aimed to investigate IEQ performance in office buildings in Australia. The project has been conducted in close consultation and collaboration with key stakeholders of the property industry (buildings owners, tenants and consultants), government (National Australian Built Environment Rating Scheme – NABERS) and the Green Building Council of Australia (GBCA). BOSSA has tools for assessing IEQ via a Post-Occupancy Evaluations (BOSSA Time-Lapse) and high-resolution diagnostics via 'right-here-right-now' surveys (BOSSA Snap-Shot) along with *in situ* measurements of key IEQ parameters (BOSSA Nova). Details about the project's tools and database have been outlined elsewhere (Candido et al, 2015).

Apart from background survey questions addressing participants' gender, age, type of work, time spent in buildings, workspace arrangement, etc., there are thirty-one questionnaire items from the BOSSA Time-Lapse survey asking building occupants to assess their satisfaction with their workspace and building, covering nine broad IEQ dimensions, namely spatial comfort, indoor air quality, personal control, noise distraction and privacy, connection to outdoor environment, building image and maintenance, individual space, thermal comfort and visual comfort. There are also four overall satisfaction items in use: work area comfort, building satisfaction, productivity and health. The current analysis focus on the general impact of workplace layout on occupant satisfaction, thus the questionnaire items which are more building-related, such as external view, shading, personal control, building cleanness and maintenance were not included. Table 1 lists the BOSSA Tim-Lapse IEQ questionnaire items used in this study.

The current research database comprises a total of approximately 7,000 responses from BOSSA Time-Lapse surveys conducted in 65 buildings Australia-wide. Most buildings are fully air-conditioned with open-plan fit-outs (with/without partitions), fixed or flexi-desking workspace policies, including a mix of ABW, conventional open-plan and private offices. Building size range from 2,000m$^2$ to 62,000m$^2$ and the vast majority hold current energy performance and/or indoor environments ratings from the NABERS and/or the GBCA's Green Star-Performance tool. Building metrics information and floor plans, including workspace layout, are collected for each building entering the database.

Apart from occupant surveys, BOSSA also collates building metrics information and floor plans, including workspace layout, depending on the availability. Details arising from this database enabled the workspace analysis presented and discussed on this paper.

Table 1 List of BOSSA Time-Lapse IEQ questionnaire items adopted in the current analysis

| Dimensions and indices | Questionnaire items | Survey questions | Rating scale |
|---|---|---|---|
| Spatial comfort and individual space | Space for breaks | This building provides pleasant spaces (e.g. indoor or outdoor green space, break-out areas) for breaks and relaxation. | 1= Disagree ~ 7= Agree |
| | Interaction with colleagues | How do you rate your normal work area's layout in terms of allowing you to interact with your colleagues? | 1= Dissatisfied ~ 7= Satisfied |
| | Personalisation of work area | My normal work area can be adjusted (or personalised) to meet my preferences. | 1= Disagree ~ 7= Agree |
| | Space to collaborate | The building provides adequate formal and informal spaces to collaborate with others. | 1= Disagree ~ 7= Agree |
| | Comfort of furnishing | Please rate how comfortable your work area's furnishings are (including chairs, desk, equipment, etc). | 1= Uncomfortable ~ 7= Comfortable |
| | Amount of workspace | Please rate your satisfaction with the amount of space available to you at your normal work area. | 1= Dissatisfied ~ 7= Satisfied |
| | Storage space | Please rate your satisfaction with the amount of personal storage space available to you. | 1= Dissatisfied ~ 7= Satisfied |
| Indoor air quality and thermal comfort | Air quality | Please rate your satisfaction with the overall air quality in your work area. | 1= Dissatisfied ~ 7= Satisfied |
| | Temperature in winter | Please rate the temperature conditions of your normal work area in winter. | 1= Uncomfortable ~ 7= Comfortable |
| | Temperature in summer | Please rate the temperature conditions of your normal work area in summer. | 1= Uncomfortable ~ 7= Comfortable |
| Noise distraction and privacy | Unwanted interruption | The work area's layout enables me to work without distraction or unwanted interruptions. | 1= Disagree ~ 7= Agree |
| | Visual privacy | My normal work area provides adequate visual privacy (not being seen by others). | 1= Disagree ~ 7= Agree |
| | Sound privacy | My normal work area provides adequate sound privacy (not being overheard by others). | 1= Disagree ~ 7= Agree |
| | Noise | Please rate your satisfaction with the overall noise in your normal work area. | 1= Dissatisfied ~ 7= Satisfied |
| Visual Comfort | Lighting | Please rate your satisfaction with the lighting comfort of your normal work area (e.g. amount of light, glare, reflections, contrast)? | 1= Dissatisfied ~ 7= Satisfied |
| | Access to daylight | Please rate your satisfaction with the access to daylight from your normal work area. | 1= Dissatisfied ~ 7= Satisfied |
| Personal control and building image | Degree of freedom to adapt | All things considered, how satisfied are you with the degree of freedom to adapt your normal work area (air-conditioning, opening the window, lighting, etc.) to meet your own preferences? | 1= Dissatisfied ~ 7= Satisfied |
| | Building aesthetics | Please rate the overall visual aesthetics of this building. | 1= Dissatisfied ~ 7= Satisfied |
| Overall satisfaction | Overall work area comfort | All things considered, how satisfied are you with the overall comfort of your normal work area? | 1= Dissatisfied ~ 7= Satisfied |
| | Overall building | How satisfied are you with this building overall? | 1= Dissatisfied ~ 7= Satisfied |
| | Productivity | Productivity How does your work area influence your productivity? | 1= Negatively ~ 7= Positively |
| | Health | How does your work area influence your health? | 1= Negatively ~ 7= Positively |

## 2.2 Workspace layouts

BOSSA Building Metrics and floor plans, when available, of 30 buildings were analyzed for this research paper. Based on the work of Duffy (1997) on spatial layout, workspaces were classified into three broad categories: conventional open plan (Hive, n = 2,301), multi-space workspace (ABW, n = 2,566) and private workspace (Cell, n = 304). The average size of buildings with ABW workspaces is almost twice as large as the ones with Hive layout (41,163m$^2$ and 21,820m$^2$, respectively). Since private workspaces are increasingly rare in Australia (and only existed in a few types of industries), there were much smaller sample

size (304) in Cell layout than the other two. Nonetheless, the Cell sample size is still statistically large.

### 2.3 Statistical analysis

The one-way Analysis of Variance (ANOVA) was carried out to examine whether different workplace layouts significantly are associated with building occupant satisfaction. However, one of the problems with this null hypothesis testing is that even the most trivial effect will become statistically significant if enough people are tested (Field, 2013). As can be expected from the large sample sizes in the current BOSSA surveys (Table 2), the omnibus ANOVA tests revealed highly significant differences ($p < 0.001$) for all 22 questionnaire items. To solve this issue, the effect size[1](ES) measures were adopted to answer the research question of how important these statistically significant differences really are.

In this analysis, a common measure of ES—*Cohen's d* (Cohen, 1988, 1992), was adopted when comparing two means. It is calculated by Equation (1) and (2).

$$d = \frac{\mu_1 - \mu_2}{\sigma} \quad (1)$$

$$\sigma = \sqrt{\frac{(N_1 - 1)\sigma_1^2 + (N_{21} - 1)\sigma_2^2}{N_1 + N_2 - 2}} \quad (2)$$

where $\mu_1$ and $\mu_2$ refer to the mean value for two groups, $N_1$ and $N_2$ refer to the sample size of two groups.

Another common effect size, the Pearson correlation coefficient *r*, was also employed in the analysis when examining the association between two parameters. It is measured on a standard scale ranging between -1.0 and +1.0. As such, the absolute value of the correlation coefficient is an effect size that summarizes the strength of the relationship. All the statistical analysis was conducted in IBM SPSS, Version 22.

## 3 Results and Discussions

The mean occupant responses are illustrated in Figure 2, with a breakdown of three different workplace layouts. ABW was associated with higher satisfaction ratings than the other two in 12 IEQ questionnaire items, except for storage space, unwanted interruption, visual privacy, sound privacy, noise and lighting; ABW also outperforms the conventional open-plan and private workspace in all four overall satisfaction questionnaire items. However, the causality of these associations *cannot* be stated firmly due to the existence of potential confounding variables, mostly building-specific features, such as architectural and interior design quality, building facility quality and standard of maintenance, etc.

[1] Effect size is an objective and (usually) standardized measure of the magnitude of the observed effect. (Field, 2013).

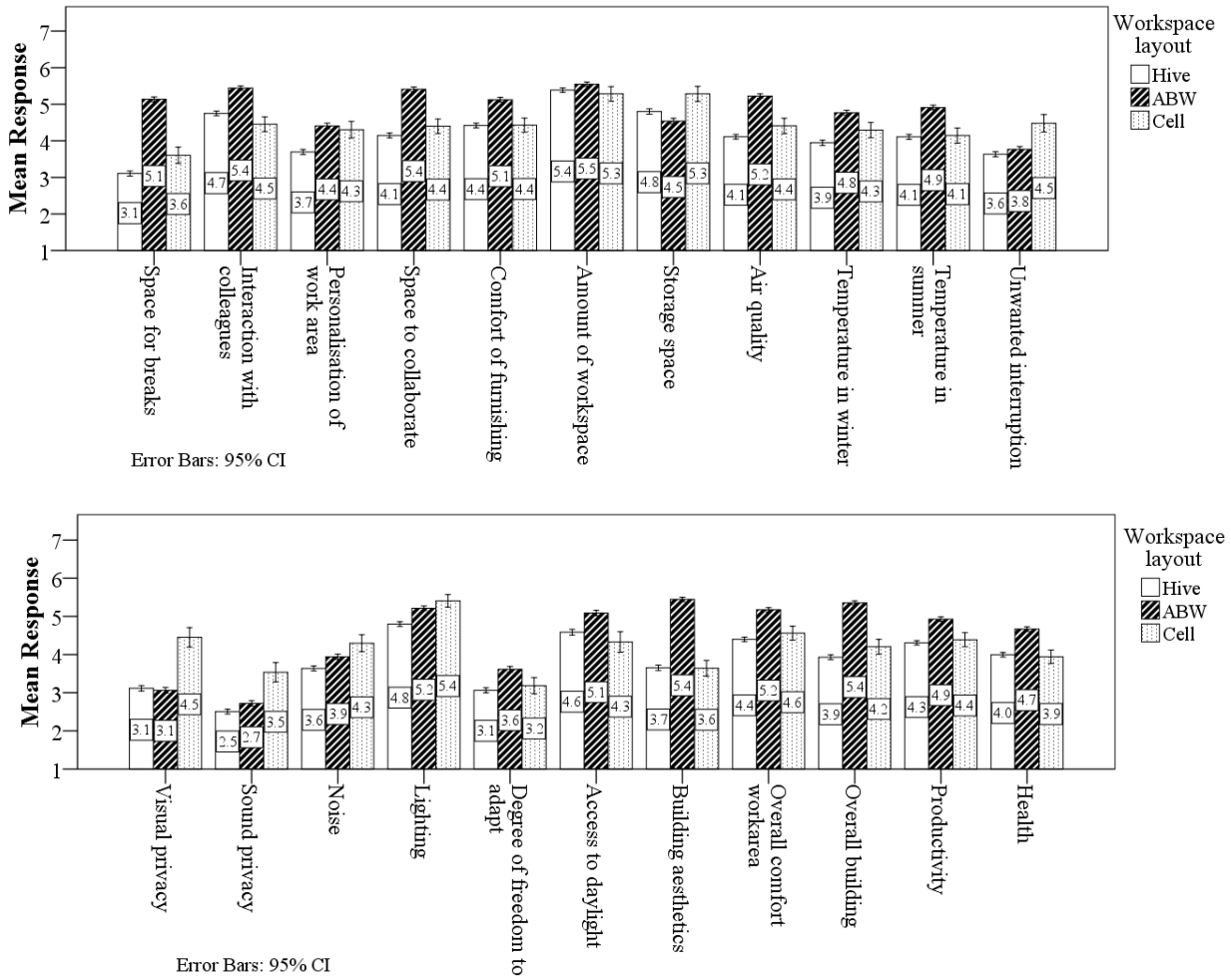


Figure 2 Breakdown of mean occupant responses in IEQ questionnaire items in three workplace layouts.

### 3.1 Workplace layout & occupant satisfaction with IEQ dimensions

ANOVA suggested highly significant mean occupant satisfaction across three different workplace layouts in 22 questionnaire items. To measure the magnitude of the effects, Cohen's *d* was calculated for the ABW vs. Hive and ABW vs. Cell pairwise comparisons; the Hive vs. Cell comparison was of no interest in this study, thus was not calculated. Cohen suggested that *d*=0.2 be considered a *small* effect size, 0.5 represents a *medium* effect size and 0.8 a *large* effect size (Cohen, 1988, 1992). This means that if two groups' means don't differ by 0.2 standard deviations or more, the difference is **trivial**, even if it is statistically significant (Statistics for Psychology, accessed 07-01-2016). In Cohen's terminology, a *small* effect is one in which there is a real effect but can be observed only through "careful study"; a *large* effect is consistent enough that could be obvious to the "naked eye". The authors thus believe that a medium or large size effect is of more practical meaning in the real world than the small size one. Table 3 reports the 7 questionnaire items that returned medium or large effects ($d \geq 0.5$) for either comparison.

Table 3 demonstrates that occupant satisfaction with space for breaks and building aesthetics was much higher in ABW than in Hive or Cell (representing large effects); ABW also exceeded the other two in respect to interaction with colleagues, space to collaborate, and air quality (medium effects); Cell performed better than ABW and Hive in terms of visual and sound privacy (medium effects).

Table 3 The effect of workplace layouts on occupant satisfaction in BOSSA IEQ questionnaire items (only medium or large effects are reported)

| IEQ questionnaire items | | Hive | ABW | Cell |
|---|---|---|---|---|
| Space for breaks | Mean | 3.11 | 5.14 | 3.61 |
| | ES (Cohen's *d*) | ABW vs. Hive | | 1.18 |
| | | ABW vs. Cell | | 0.92 |
| Interaction with colleagues | Mean | 4.75 | 5.44 | 4.45 |
| | ES | ABW vs. Hive | | 0.45 |
| | | ABW vs. Cell | | 0.66 |
| Space to collaborate | Mean | 4.15 | 5.41 | 4.40 |
| | ES | ABW vs. Hive | | 0.76 |
| | | ABW vs. Cell | | 0.64 |
| Air Quality | Mean | 4.11 | 5.22 | 4.41 |
| | ES | ABW vs. Hive | | 0.71 |
| | | ABW vs. Cell | | 0.54 |
| Visual Privacy | Mean | 3.12 | 3.06 | 4.45 |
| | ES | Cell vs. Hive | | 0.70 |
| | | Cell vs. ABW | | 0.73 |
| Sound Privacy | Mean | 2.50 | 2.72 | 3.54 |
| | ES | Cell vs. Hive | | 0.61 |
| | | Cell vs. ABW | | 0.46 |
| Building aesthetics | Mean | 3.66 | 5.45 | 3.64 |
| | ES | ABW vs. Hive | | 1.11 |
| | | ABW vs. Cell | | 1.25 |

Above results seemed to be intuitive and reasonable regarding visual privacy, sound privacy and building aesthetics—the enclosed/private offices with Cell layout are naturally of higher visual and sound privacy than the other open-plan ones; the innovative activity-based working break the rules of traditional workplace arrangement and fit-out contributing to a new and appealing appearance to the ABW buildings.

Regarding the three questionnaire items related to spatial comfort, specific spatial-related attributes of all sampled buildings in each type of workspace layout were examined and quantified, shown in Table 2. With the ABW buildings being specifically designed to integrate space for break out and both formal and informal spaces for collaboration, it may be unsurprising that ABW returned higher satisfaction when compared to both Hive and Cell. On the other hand occupant satisfaction with respect to "How do you rate your normal work area's layout in terms of allowing you to interact with your colleagues" suggests that specific amenities integrated in ABW do succeed in facilitating the desired interaction with colleagues. Although surveyed buildings with ABW layout have higher amount of floor area available per desk (16 $m^2$) than ones with Hive layout (13 $m^2$), the average work area per desk for ABW (5 $m^2$) is less than that for Hive (8 $m^2$). This could result from the nature of flexi-desk arrangement in ABW settings where the same desk is supposed to be shared by different people, or the fact that desks (flexi or fixed) equipped in buildings with ABW layout are simply not enough, or both.

ABW's superiority to Hive and Cell in achieving higher satisfaction with air quality may probably due to the prevalent flexi-desk arrangement in this layout. In a separate analysis of the 7 ABW buildings (Kim et. al 2015), the authors found that flexi-desk arrangement achieved significantly higher occupant satisfaction regarding air quality than the fixed-desk arrangement. Those participants reporting flexi-desk arrangement as their primary workspace arrangement were directed to another question about whether the indoor environmental quality influences their seat selection (seven-point scale with 1= disagree and 7= agree). The results showed that over 80% of the respondents agreed (the top three levels on the rating scale) that IEQ affects their decision of seat selection. Due to the nature of

activity-based working, a flexi-desk arrangement is prevalent in ABW buildings. Among all 7 buildings with ABW layout, 87.3% of the participants have reported that flexi-desk is their primary workspace arrangement. Participants' enhanced level of perceived control over the indoor environment, as discussed in Kim and de Dear (2012), goes some way towards explaining why ABW achieved higher satisfaction ratings in air quality than the other two types.

### 3.2 Workplace layout & overall satisfaction

Similarly, Cohen's *d* was calculated for ABW vs. Hive and ABW vs. Cell pairwise comparisons for the four overall satisfaction items, shown in Table 4. ABW surpassed the other two in the overall building satisfaction, representing a large size effect; ABW also lead in the three types of workplace layout with respect to work area comfort, productivity and health, representing (near) medium size effects. Again, one should be cautious not to overstate this conclusion since the confounding variables were not controlled in the analysis.

Table 4 The effect of workplace layouts on four BOSSA overall satisfaction

| Questionnaire item | | Hive | ABW | Cell |
|---|---|---|---|---|
| Work area comfort | Mean | 4.40 | 5.18 | 4.56 |
| | Effect Size (Cohen's *d*) | ABW vs. Hive | 0.54 | |
| | | ABW vs. Cell | 0.45 | |
| Building Satisfaction | Mean | 3.93 | 5.35 | 4.20 |
| | Effect Size (Cohen's *d*) | ABW vs. Hive | 0.92 | |
| | | ABW vs. Cell | 0.83 | |
| Productivity | Mean | 4.31 | 4.93 | 4.39 |
| | ES (Cohen's *d*) | ABW vs. Hive | 0.42 | |
| | | ABW vs. Cell | 0.36 | |
| Health | Mean | 4 | 4.67 | 3.94 |
| | ES | ABW vs. Hive | 0.44 | |
| | | ABW vs. Cell | 0.48 | |

Candido et. al (2015) employs multiple regression analyses to quantify how occupants' ratings on the 9 IEQ dimensions contribute to the ratings on the IEQ dimensions all significantly predict general satisfaction to different degrees. In this study, correlation analysis was carried out to examine how the superiority of ABW in promoting occupants' general satisfaction is related to its advantage/disadvantage in 18 IEQ questionnaire items. Figure 3 illustrates Pearson's *r* between 4 overall satisfaction and 18 IEQ questionnaire items for the ABW buildings. To interpret these effect sizes, an *r* of 0.1 represents a weak or *small* association, 0.3 represents a *medium* correlation and 0.5 or higher represents a strong or *large* correlation (Cohen, 1988, 1992).

The overall work area comfort and overall building satisfaction generally have higher correlation with IEQ items compared with productivity and health. Specifically, overall work area comfort and overall building satisfaction have a stronger correlation ($r > 0.5$) with respect to the IEQ items in which ABW outdistanced Hive and Cell (large or medium size effects) namely: space for breaks, interaction with colleagues, space to collaborate, air quality and building aesthetics. It is evident that the advantage of ABW over Hive and Cell is more conspicuous in terms of work area comfort and building satisfaction (medium or large size correlation) than in respect to productivity and health (near medium size correlation).

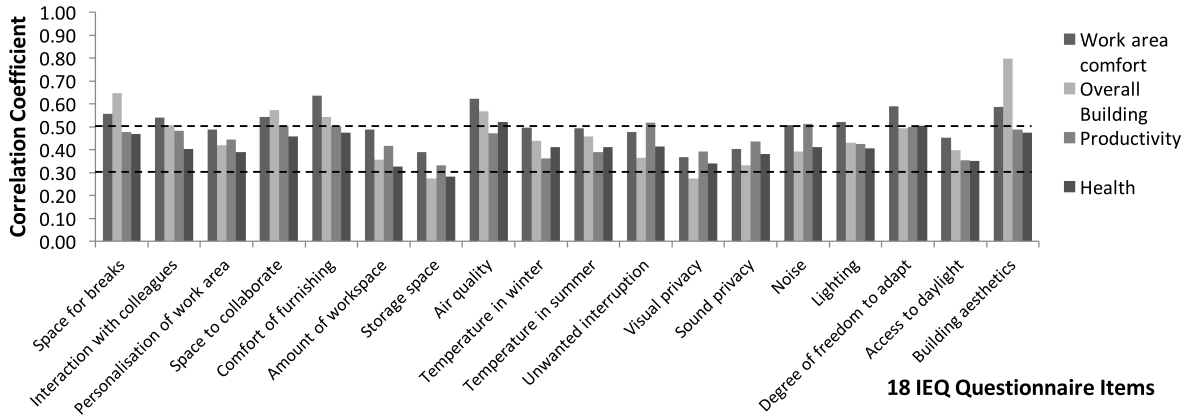


Figure 3 Correlation between IEQ questionnaire items for ABW.

## 4 Conclusions

This paper analyzed post-occupancy evaluation results from 5171 building occupants in 30 buildings from the Building Occupant Survey System Australia—BOSSA, specifically looking into the impact of different workspace layouts on building occupant satisfaction in key IEQ dimensions, perceived productivity and health. The following results can be obtained from this study:

- buildings occupants, generally, were more satisfied with ABW layout than Hive and Cell layouts in IEQ related issues, especially on space for breaks, interaction with colleagues, space to collaborate, air quality and building aesthetics, all representing medium or large size effects.
- ABW is also in association with higher occupant satisfaction than the Hive and Cell in the overall work area comfort (medium size effect), the overall building satisfaction (large size effect), perceived productivity and health (near-medium size effect).
- Not surprisingly, Cell layouts that afford private workspaces are associated with higher satisfaction scores in sound privacy and visual privacy.
- Although one should be discreet in generalizing the above mentioned trends, sampled buildings with ABW layout do provide more spaces for breaks, meetings and collaboration than the other two. Furthermore, flexi-desk arrangement that is popular in ABW also gives occupants more flexibility and control in choosing their workstation indoor environment with ideal air quality.

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