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Aural related implications of the open plan office

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Abstract: The open plan office is now a standard design approach for new and retrofitted commercial buildings. The open work environment is considered to improve communication and collaboration between colleagues, facilitating more efficient and faster responsiveness and decision making. The removal of walls in open plan offices allows for an increase in the density of occupants and is also advantageous in aiding effective air distribution. However, research has shown that the benefits of improved access to colleagues can be overshadowed by the impact of increased noise, visual related disturbances and a loss of privacy. This paper reports on a post occupancy evaluation of a number of commercial office buildings (Green Star rated and non-rated buildings) in Adelaide, South Australia, focusing on acoustic privacy in the buildings as perceived by the occupants. The evaluation found that occupants in the Green Star rated buildings had a decreased satisfaction when compared to the occupants in the non-rated buildings particularly in relation to their perceptions of noise overall, noise generated from within and outside of the building, the frequency of unwanted interruptions and also privacy. Occupants expressed concern that these factors were affecting their overall comfort, productivity and health. The similarities and differences between the buildings and their occupants will be discussed. Through identifying and learning from the aspects impacting on aural comfort, we can change our approach to the design of work places and improve the built environment.

Keywords: office buildings; occupant satisfaction; post occupancy evaluation; noise

1. Introduction

It is estimated that 30 percent of our lifetime is spent at work (IAC, 2016). Given this high percentage it is important that these spaces provide us with the same qualities we expect from other environments. Commercial buildings designed and constructed following 'green' principles are credited with reducing negative impact on human health and providing internal environments which result in high levels of occupant satisfaction and increased productivity (Chong, 2007). Research by Wagner et al (2007) found that buildings which "meet the occupants' needs for comfort and workspace quality" are conducive to

healthier and more productive personnel. It has been found however, that the inclusion of 'green' characteristics can negatively impact on an occupants' experience of the internal space (Leaman and Bordass, 2001; 2007; Turner and Frankel, 2008; Baird et al, 2012). For example, increased levels of day light is encouraged in 'green' principles, but this can result in increased glare discomfort for occupants (Leaman and Bordass, 2007). Kim and de Dear (2013) found that dissatisfaction of "'noise level', 'sound privacy' and 'visual privacy' tended to increase considerably in open-plan layouts compared to private offices". 'Green' principles promote open-plan offices for increased penetration of light and distribution of air (Den-Ouden, 1981). The above studies highlight a clear conflict between expectations and actual user experiences.

This paper reports on a post occupancy evaluation of a number of commercial office buildings in Adelaide, South Australia. The main aim of the research was "to determine if commercial office buildings in the City of Adelaide which claim to be 'green' are indeed outperforming non-green buildings not only in their environmental performance but also in their ability to provide internal environments which result in higher satisfaction to the occupants" (Menadue, 2014). The research included assessment of energy and water consumption, building design, the analysis of internal environment measurements and the results of occupant surveys. In this research, 'green' buildings were divided into two groups; 'Green Star' referring to new or retrofitted buildings assessed and accredited by the nationally accepted environmental performance rating tool Green Star, which commenced in Australia in 2003 (GBCA, 2015) and 'Green Intentions' buildings which incorporated green features not found in buildings of a similar age, but had not been assessed against an environmental rating tool. 'Non-green' buildings claim no green credentials and will be referred to as 'Conventional' buildings in this paper.

This paper focuses on the results of investigations into aural related disturbances and the impact of these disturbances on perceived privacy of building occupants. The investigations include occupant satisfaction surveys and also review of the internal arrangement of the office spaces. This paper is a continuation of the earlier publication by the authors (Menadue et al, 2013) which reported on the correlation between dissatisfaction with noise and visual disturbances and occupants' sense of overall comfort and perceptions of health in a building which in turn can impact on perceived productivity.

2. Research method

The research involved extensive field work to evaluate commercial office buildings in the city of Adelaide, post occupancy. The comparison of 'green' and conventional buildings allowed more recent buildings in Adelaide to be directly assessed against buildings which were 'typical' of their era. It is important to note that the majority of commercial construction in the last decade in Adelaide is Green Star rated, meaning the conventional buildings in this study were older. Also, Adelaide is typical of most Australian cities with only 2-3 percent of building stock being replaced each year (ASBEC, 2008).

As this paper focuses on aural issues in internal spaces, only methods for collecting data relating to these aspects will be discussed.

2.1. Building selection

Various approaches were undertaken to identify buildings to include in the study, such as contact with building management companies, management of organisations within the buildings and government officials. All participating buildings needed to be located in the Adelaide CBD, have been occupied for at least 12 months prior to the study commencing and have at least 80 percent of their lettable area for

commercial office activities. Other than these stipulations, there was no restriction on size of building, number of floor levels or date of construction. In all, nine buildings participated in the study with a combined total of 135,000m^2 of net lettable floor area. The study included four buildings in the 'Conventional' category described in Table 1 (building A to D). The 'Green Star' category also had four buildings (Table 2, building E to H), while the single building in the 'Green Intentions' category is described in Table 3 (building J).

Table 1: Characteristics of the Conventional buildings.

Characteristic	Building number			
	A	B	C	D
Construction period	late 1970s	1970s	late 1990s	1980s
Occupancy type	owner occupied	owner occupied	multi-tenanted	owner occupied
Net lettable area	7020m^2	24000m^2	20100m^2	13800m^2
Average floor plate area	640m^2	1200m^2	1900m^2	1350m^2
Floor levels (above ground)	11	17	11	11
Number of occupants	450	1400	1200	820
Area per occupant	15.6m^2	21.5m^2	13.8m^2	16.8m^2
Façade type	concrete facade	concrete facade	concrete facade	glazed
Extent of glazing	small and evenly distributed	small and evenly distributed	50% of facade	90% of facade
Floor arrangement type	mix of cubicles with high, low and no partitions	mix of cubicles with low and no partitions	mix of cubicles with low and no partitions	mix of cubicles with high and low partitions

Table 2: Characteristics of the Green Star buildings.

Characteristic	Building number			
	E	F	G	H
Green Star rating	5 Star as built	5 Star as built	4 Star design	4 Star design (retrofit)
Construction period	2007	2008	2008	2009
Occupancy type	multi-tenanted	multi-tenanted	multi-tenanted	multi-tenanted
Net lettable area	31000m^2	12380m^2	7200m^2	20400m^2
Average floor plate area	1500m^2	950m^2	900m^2	1200m^2
Floor levels (above ground)	21	13	8	17
Number of occupants	2000	850	350	1280
Area per occupant	15.0m^2	13.8m^2	37.7m^2	15.7m^2
Façade type	glazed and concrete facade	glazed and concrete facade	glazed and concrete facade	glazed
Extent of glazing	80% high performance double glazing	70% high performance double glazing	70% high performance glazing	50% high performance glazing
Floor arrangement type	mix of cubicles with low and no partitions	cubicles with no partitions	mix of cubicles with low and no partitions	mix of cubicles with low and no partitions

Table 3: Characteristics of the Green Intention building.

Characteristic	Building number
	J
Construction period	2005
Occupancy type	owner occupied
Net lettable area	485m^2
Average floor plate area	242m^2
Floor levels (above ground)	2
Number of occupants	45
Area per occupant	10.5m^2
Façade type	glazed, clad and masonry
Extent of glazing	under 50%
Floor arrangement type	cubicles with no partitions

2.2. Occupant satisfaction survey

Occupants in the study buildings were surveyed to obtain data on their satisfaction with the internal thermal, light and aural conditions; the workplace environment and their perceptions of their personal overall comfort, health and productivity. The online survey was in the form of yes/no and seven point scale questions with many of the questions including a comment box for additional feedback. This research used the Building Use Studies (BUS) survey under licence with modifications permitted, such as additional questions on privacy (aural and visual) and organisational based issues such as communication in the workplace, work group morale and personal happiness with work. The BUS survey has been used extensively in other research studies in Australia (Leaman et al, 2007, Paevere and Brown, 2008) and internationally (Baird, 2010) including the PROBE studies in the UK (Leaman and Bordass, 2001).

In the spring of 2010 the survey was distributed by building and organisation representatives via email circulation lists, with a follow up email two weeks later. The survey was circulated to approximately 2600 building occupants with over 600 responses received. Although all participating organisations within the nine study buildings agreed to partake in the survey, ultimately responses were only received from seven of the buildings with no survey responses from buildings D and H.

2.3. Analysis

For the occupant survey questions with a scale response, a mean score was calculated from individual responses for each building and also for each category of building. In addition, both quantitative and qualitative results from the survey were analysed using SPSS software and NVIVO software respectively. Quantitative question responses were statistically analysed using multiple linear regression to identify predictor variables for overall comfort, productivity and health, which were considered the 3 key issues to occupant satisfaction. Qualitative results were coded by emergent themes within each survey question to identify key topics raised by the survey respondents.

The following section focuses on the survey questions related to aural related disturbances and the impact of these disturbances on perceived privacy within the building. And finishes with a discussion on the correlation of responses to these questions and how occupants rated their overall comfort, productivity and health.

3. Results

When responding to questions in the survey, building occupants were asked to consider the typical work conditions experienced in their normal work area. Relative to noise, the survey questions cover the issues of *Noise Overall*, *Noise from Colleagues*, *Noise from Other People*, other *Noise from Inside*, other *Noise from Outside* and the frequency of *Unwanted Interruptions*. These questions were on a 7 point scale (Menadue, 2014).

Figure 1 compares the mean responses to the noise questions in the survey for the Conventional, Green Star and Green Intentions buildings. For ease of reading the data expressed in the spider graph (Figure 1), the *Unwanted Interruptions* question which had an optimum response of 1 has been transposed to 7. For example, where the actual mean response of a question with an optimum response of 1 is 4.69 (shown in the table data) in the spider graph it will be presented as 2.31 (7 - 4.69) (Menadue, 2014). Table 4 lists the mean and standard deviation for each question in the Conventional and Green Star buildings along with the statistical significance of the difference in their means. Table 5 provides this information comparing the Green Star and Green Intentions buildings.

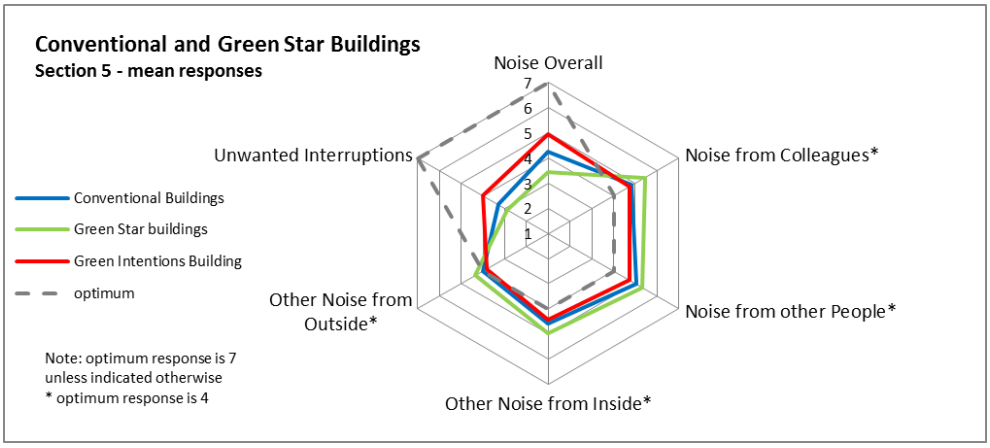

Figure 1: Conventional buildings, Green Star buildings and the Green Intentions building – mean responses to 'noise' survey questions

It is found in both of the comparisons that the occupants' of the Green Star buildings have a lower level of satisfaction for noise related issues. It is seen that the difference in mean response to *Noise Overall* when the Conventional and Green Star buildings are compared and also when the Green Star and Green Intention buildings are compared is statistically significant indicating diverse perceptions of noise are occurring.

Figure 2 shows the response distribution within the three building categories to the six noise related questions in the occupant survey. For all questions related to this issue the Green Intentions building received the closest to optimum mean score, while the Green Star Buildings received the worst scores of the three building types for *Noise Overall*, *Noise from Colleagues* and *Others*, *Noise from* both *Inside* and **Outside** and occupants in the Green Star buildings suffered from the most *Unwanted Interruptions*.

Table 4: 'Noise' survey question results for Conventional and Green Star buildings

Question	Building category	Optimum	Mean[1]	Standard deviation	Significance of mean difference[2]
Noise overall	Conventional	7	4.24	1.83	p<0.01
	Green Star		3.43	1.83	
Noise from colleagues	Conventional	4	4.85	1.42	p<0.01
	Green Star		5.48	1.27	
Noise from other people	Conventional	4	5.04	1.53	p<0.05
	Green Star		5.32	1.44	
Other noise from inside	Conventional	4	4.60	1.45	p<0.01
	Green Star		4.98	1.55	
Other noise from outside	Conventional	4	4.01	1.84	p<0.05
	Green Star		4.38	1.75	
Unwanted interruptions	Conventional	1	4.69	1.81	p<0.01
	Green Star		5.12	1.55	

[1] Building category with closest to optimum mean score is highlighted
[2] T-test for significance of difference in means

Table 5: 'Noise' survey question results for Green Star and Green Intention buildings

Question	Building category	Optimum	Mean[1]	Standard deviation	Significance of mean difference[2]
Noise overall	Green Star	7	3.43	1.83	p<0.01
	Green Intentions		4.95	1.56	
Noise from colleagues	Green Star	4	5.48	1.27	p<0.05
	Green Intentions		4.71	0.78	
Noise from other people	Green Star	4	5.32	1.44	p>0.05
	Green Intentions		4.71	1.49	not significant
Other noise from inside	Green Star	4	4.98	1.55	p>0.05
	Green Intentions		4.43	1.33	not significant
Other noise from outside	Green Star	4	4.38	1.75	p>0.05
	Green Intentions		3.81	1.66	not significant
Unwanted interruptions	Green Star	1	5.12	1.55	p<0.05
	Green Intentions		4.00	1.95	

[1] Building category with closest to optimum mean score is highlighted
[2] T-test for significance of difference in means

Survey respondents were able to provide comment in relation to noise issues. Below is a summary of the comments from occupants in the Conventional and Green Star buildings; the worst effected by noise. In the Conventional buildings the highest percentage (28%) of respondents' comments related to noise from colleagues discussing how voices easily travelled across the open plan environment with these voices generally being part of phone or meeting conversations, described by one respondent "as a result of our work practices and needs". This issue was also raised in the Green Star Buildings with the noise in Green Star building E said to travel between floors where the multistorey atrium was next to work spaces. Almost a quarter (23%) of comments in the Conventional buildings and almost a third (30%) in the Green Star buildings related to other noise from inside such as fax machines and printers,

phones ringing and the constant hum of HVAC systems. In the Green Star Buildings, 54% of comments regarded issues such as a lack of sound proofing of meeting rooms and quiet rooms and also the proximity of meeting rooms and circulation spaces to work areas. The issue of lack of sound proofing was also raised in the Conventional buildings along with the noise generated by large work groups gathering for meetings, training or social events in the open plan area because the buildings do not provide other areas such as large meeting rooms for them to gather in. Many respondents in the Green Star buildings spoke of wearing headphones to minimise noise which they described as a consequence of the open plan floor (Menadue, 2014).

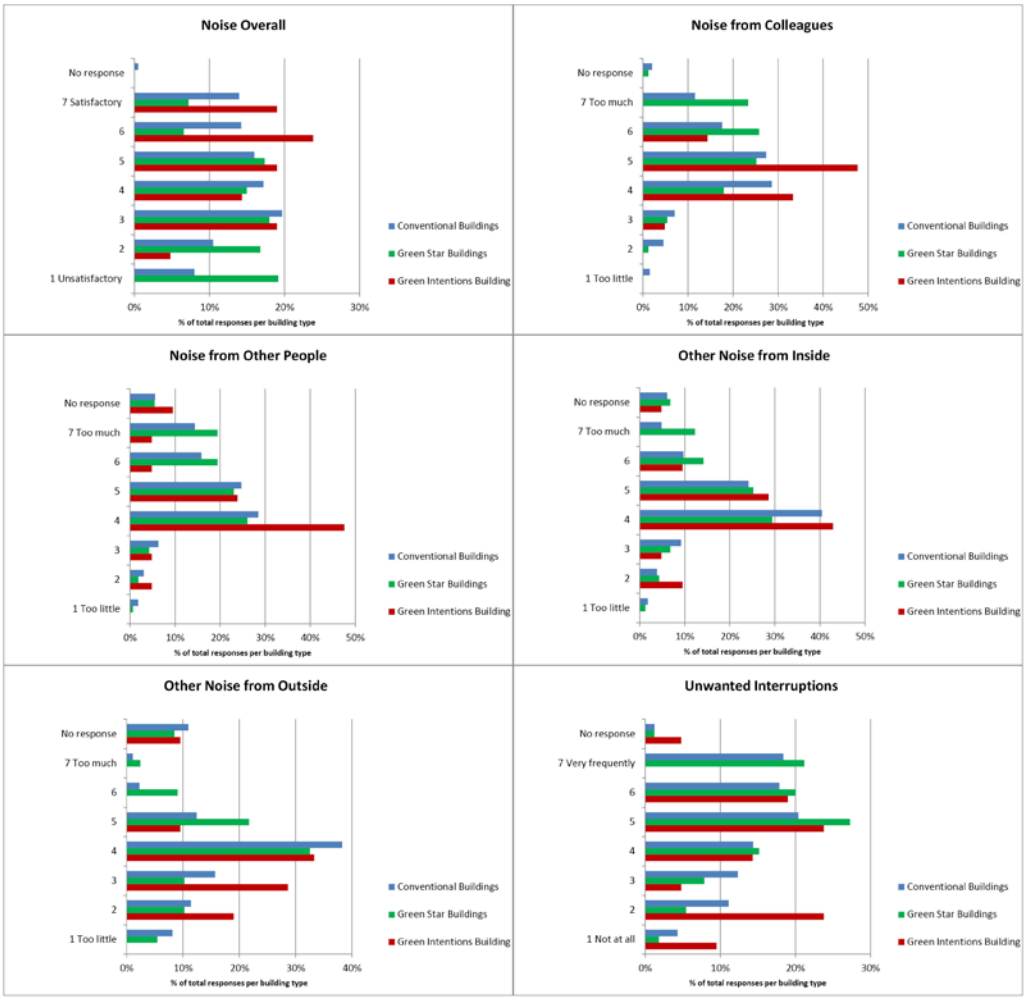

Figure 2: Response distribution to survey ‘Noise’ questions

Another question in the occupant satisfaction survey asked respondents to rate their personal workspace visual and acoustic privacy, specifically on their ability to work effectively. Figure 3 shows the distribution of responses to this question within the three building categories. Again the Green Star

building received the farthest from optimum mean score of 2.59. The Conventional building received a mean score of 3.18, while the Green Intention building rated closest to optimum, with a mean score of 4.50. The comments from occupants in the Green Star buildings relating to the issue of privacy indicated that the problem was created by the open plan layout. The low partitions between work stations meant respondents felt their computer screens could easily been seen by others with one respondent saying they felt "self-conscious". Also, conversations could easily be heard across the floor with respondents often overhearing what they believed were confidential work related conversations between management and other staff. One respondent suggested "proper privacy screens so we can have some time out from constantly seeing and hearing others all day every day" (Menadue, 2014)

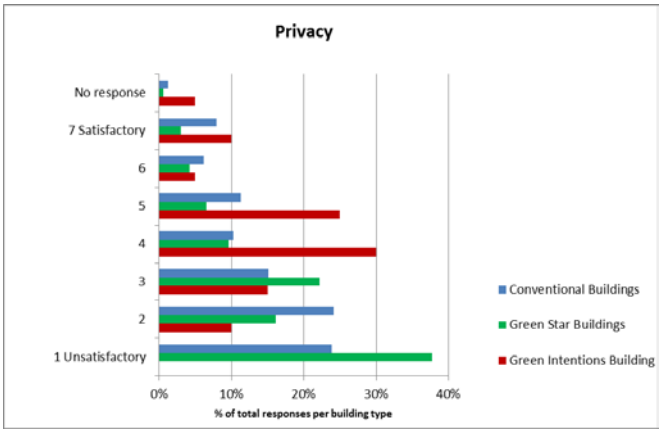

Figure 3: Response distribution to survey 'Privacy' question

Given the poor satisfaction level for acoustics and privacy within the Green Star buildings it is worth reviewing the spatial arrangements of the floor plates. Figure 4 shows a typical floor in each of the three building categories. The Green Star buildings are all recent construction or substantial redevelopments and have been designed for an open-plan office. There is efficiency of spatial arrangement evident in the plan with plant, vertical transportation and amenities typically located on eastern and western facades and offices and meeting rooms internalized to maximise connection to natural light and external views in the open-plan space. This results in large expanses of open area providing workspaces for up to 50 occupants. These large expanses combined with low partitions result in high visual exposure and ease of noise passage. The Conventional buildings have all introduced open-plan workspaces in recent renovations of the floor plates. Typically the partitions were higher in the Conventional buildings creating greater visual separation. Also, the size and shape of the floor plates, with centrally located plant, vertical transport and amenities divide the floor plate into smaller work zones. The Green Intentions building was designed to similar spatial principles as the Green Star buildings but on a much smaller scale. The fewer occupants combined with employees who were involved in the design process and therefore had a greater understanding of what the building was trying to achieve resulted in occupants more tolerant of noise and privacy, although unlikely less affected.

Figure 4: Floor plate arrangements in a Conventional building (left), Green Star building (middle) and the Green Intentions building (right)

In Menadue (2014) variables with strong correlations to the three key issues of occupant satisfaction: overall comfort, productivity and health, were identified. Correlations between noise and privacy variables and the key issues were only identified in the Conventional and Green Star buildings (Table 6). Despite some dissatisfaction identified with variables in the Green Intentions building the key issues rated well with overall comfort 6.14 (optimum 7), productivity 3.5 (optimum 1 on a nine point scale) and Health 5.65 (optimum 7) with noise and privacy not found to influence perceptions.

In the Conventional and Green Star buildings occupants' dissatisfied with *Noise Overall* were more likely to also have dissatisfaction with overall comfort and feel less productive, while perceptions of health were also impacted by *Noise Overall* in the Green Star buildings. Again, in the Green Star buildings, dissatisfaction with aural and visual privacy also correlated to dissatisfaction with overall comfort and reduced perceived productivity.

Table 6: Relationship between key satisfaction issues and noise and privacy

Dependent variable	Variable	Building category	Coefficient of determination (r^2)	Significance
Overall Comfort	Noise overall	Conventional	0.166	p<0.01
	Noise overall	Green Star	0.151	p<0.01
	Privacy	Green Star	0.196	p<0.01
Productivity	Noise overall	Conventional	0.149	p<0.01
	Noise overall	Green Star	0.231	p<0.01
	Privacy	Green Star	0.126	p<0.01
Health	Noise overall	Green Star	0.075	p<0.01

4. Conclusion

The results of this research and others discussed in this paper highlight that there is still much to learn from buildings in operation. Occupants' satisfaction with acoustics and privacy is typically low particularly in the Green Star buildings of this study. Further research is required into the sources and nature of the noise as well as the expectations of the occupants to truly understand the impact.

Investigation needs to be undertaken into methods for monitoring noise levels within work environments which are unobtrusive. Visible equipment and awareness of 'sound' monitoring is likely to result in occupants making behavioural changes. The idea of learning from post occupancy evaluations of buildings is not new, Hillier and Penn (1994) referred to it as the 'virtuous circle'. Improving occupant satisfaction in buildings will only come from understanding the root of the problems (Leaman and Bordass, 2007).

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