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User perspectives on outdoor noise in open-plan offices with operable windows

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Abstract

Recent research suggests that buildings with operable windows in general, and mixed-mode (MM) buildings in particular can provide improved thermal comfort and control opportunities for users. Yet, there have been concerns about outdoor noise sources like traffic or construction noise when windows are opened. Concerns like these may hinder the installation of operable windows in buildings. This paper examines 23,000 office building occupants' perspectives on noise from both sealed and naturally ventilated/MM buildings. Results suggest that occupants near operable windows are more satisfied than those near sealed windows or those far from either window type. Among occupants dissatisfied with noise, complaints about indoor noise sources --like people talking-- are about 10 times more prevalent than outdoor noise complaints.

Background

Office workers generally prefer access to a window. Studies suggest that the sunlight windows provide is relaxing; (Boubekri, et al., 1991) and the presence of a window is thought to increase motivation (Stone, 1988). Windows that are operable provide additional benefits to occupants like improved ability to manage their comfort. In fact, occupants can be comfortable over a wide range of temperatures in some buildings with operable windows (Brager et al., 2004). Since occupants can be comfortable under more conditions in such a building, HVAC system demand is reduced, which also saves energy. Unfortunately, most office buildings include sealed --rather than operable-- windows in the name of tightly controlled indoor environments. Therefore, most occupants miss these additional benefits and building owners miss out on potential energy savings.

While there are many positives to operable windows, there are potential negatives too. Dust, pollen and other pollutants may enter the building via outside air. Operable windows may present safety concerns by offering additional entry points into the building. Additionally, occupants in buildings with operable windows will likely be exposed to more outdoor noise than occupants in sealed buildings. These aspects may hinder the inclusion of operable windows in new buildings and retrofit installations in existing buildings.

To address outdoor noise as a barrier to the use of operable windows in designs, this paper analyzes occupant perceptions of outdoor noise. More specifically, it presents analysis of five variables related to outdoor noise. It compares noise responses in operable and sealed buildings; the effect of an occupant's distance from the windows; how far above ground-level noise the occupant sat; whether the building had double-paned glass in its windows; and the building's window to wall ratio. The study's sample is 92 office buildings in four countries, representing approximately 23,000 occupants.

Literature

The effect of noise on office occupants is certainly worth considering. Poor acoustic environments can interfere with communication, create annoyance, stress and impede work performance. The World Health Organization (WHO) recommends a background noise level lower than 45 db(A) for good speech intelligibility --the ability to understand others (WHO, 1980). The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) also suggests a noise level less than 45db(A) for open plan offices (ASHRAE, 2011.) Workers in open office environments report the worst acoustic problems (Jensen et al., 2005; Tuomaala et al., 2009) and this pattern persists even in 'green' rated buildings (Abbaszadeh, 2006). Occupant comments express frustration and distress about poor acoustic environments, (Moezzi et al., 2011) which may affect morale. Finally, absenteeism may also increase if acoustic conditions are bad enough (Fried et al., 2002).

The relationship between noise and the performance of office workers is especially well researched. One study showed that even noise under 85dB --the level of a commercial truck-- slowed work performance, but did not affect accuracy (Guilian et al., 1986). Noise of this sort would also hinder telephone and other conversations. (Miller, 1981). More recent work has expanded on these findings by showing that reading tasks are most affected by noise (Furnham, 2002), a common task among office workers. The frequency of noise matters as well, with unpredictable noise also being problematic for occupants (Theologus, 1974). Construction noise and sirens might fall into this category.

This paper is concerned with the degree outdoor noise is perceived to be a contributor to noise problems in offices. More specifically, noise from traffic, construction and other outdoor activities and equipment is of most interest here. It is well established that traffic noise is a particular source of noise annoyance (Griffiths et al., 1967; Matsumura, 1991; Miedema et al., 1999; Ouis, 2001). Yet, short exposures to traffic noise have not been shown to affect work performance (Ljungberg, 2007). Still, long exposures like those experienced in an office building might. Additionally, outdoor noise is certainly an irritator and may also affect work satisfaction, intent to stay and morale.

Data and Methods

The Center for the Built Environment (CBE) has developed a web-based survey about indoor environmental quality (IEQ). The survey asks about seven IEQ areas including noise (Fig. 1) and acoustics (Zagreus et al, 2004). When respondents indicate dissatisfaction with noise, they are asked follow-up questions about the sources of their dissatisfaction (Fig. 2). The list of sources includes both interior and exterior noise concerns. Respondents can write in additional sources of dissatisfaction if needed. Occupants are also offered the opportunity to write free-text comments about noise.

The survey has been continually administered in buildings since 2000. The complete dataset now includes responses from over 550 buildings and over 65,000 people.

For each building, CBE also captures over 100 building characteristics, including indicators of land use density, window to wall ratio, number of storeys, whether the windows have double-pane glass and whether the windows open. The data used in this paper represent the buildings for which all of the aforementioned factors are completed. This resulted in a sample of 92 buildings and approximately 23,000 occupants. Still, the database is statistically very powerful due to its size. The set of survey questions used is largely the same in each building, so responses can be compared across buildings.

How satisfied are you with the noise level in your workspace?

Very Satisfied  Very Dissatisfied

Figure 1. Noise satisfaction question used in the CBE survey.

Numeric data for each respondent were analyzed, as were the 2,100 free text comments about noise. Numeric data were analyzed in Excel. All numeric results are statistically significant to a 99% confidence level unless otherwise noted. Text data were analyzed in SPSS Text Analytics for Surveys. Over 80% of the comments were categorized and included in our results. The remaining comments were of miscellaneous topics unsuitable for analysis in this paper. No physical measurements were taken in conjunction with this analysis.

You have said you are dissatisfied with the acoustics in your workspace. Which of the following contribute to this problem? (check all that apply)

- People talking on the phone
- People talking in neighboring areas
- People overhearing my private conversations
- Office equipment noise
- Office lighting noise
- Telephones ringing
- Mechanical (heating, cooling and ventilation systems) noise
- Excessive echoing of voices or other sounds

- Outdoor traffic noise
- Other outdoor noise
- Other:

Figure 2. Sources of acoustics dissatisfaction question used in CBE survey.

		near window	interior
% of people	sealed	36%	60%
	operable	11%	81%

% of buildings	sealed	80%
	operable	20%

	location	%
% of buildings	downtown	62%
	urban	21%
	suburban	14%
	rural	3%

Figure 3. Summary statistics for the analyzed.

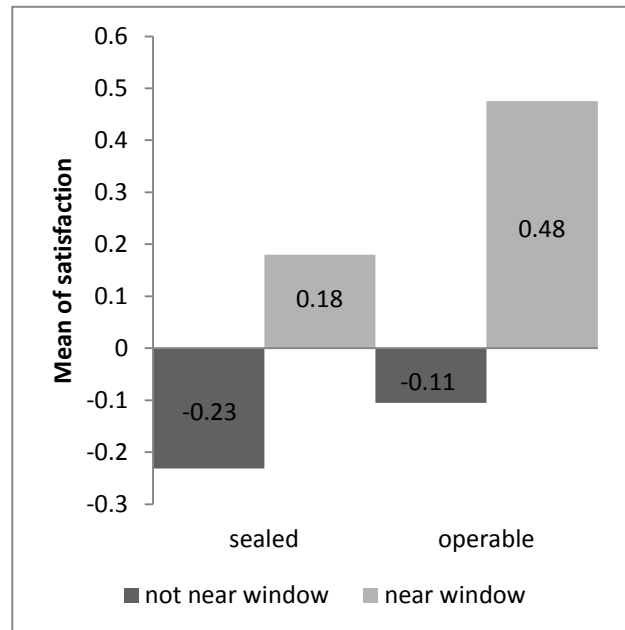


Figure 4. Noise satisfaction averages. n = 19,530.

About 2/3 of the sample buildings are in the US. The remaining buildings are in Finland, Canada and Australia. A majority of the buildings are situated in central business districts --downtowns-- densely populated areas which are likely to have high levels of outdoor noise. Eighty percent of the buildings were sealed, while 20% offered operable windows. For both sealed and operable buildings, a majority of occupants sit more than 15 feet from their nearest windows (Fig. 3).

Results

Figure 4 shows results for the 7-point noise satisfaction question used in CBE's survey. The data show that occupants in buildings with operable windows are more satisfied than their counterparts in sealed buildings (Fig. 4). More specifically, occupants near windows in operable buildings are more satisfied than their counterparts near windows in sealed buildings.

When asked about specific sources of dissatisfaction, interior noise sources were much more of a problem than outdoor ones like traffic noise (Fig. 5-6). People talking was the greatest concern. While 80% of those dissatisfied and near windows in operable window buildings cited people talking as a problem, less than 20% cited traffic noise as a problem.

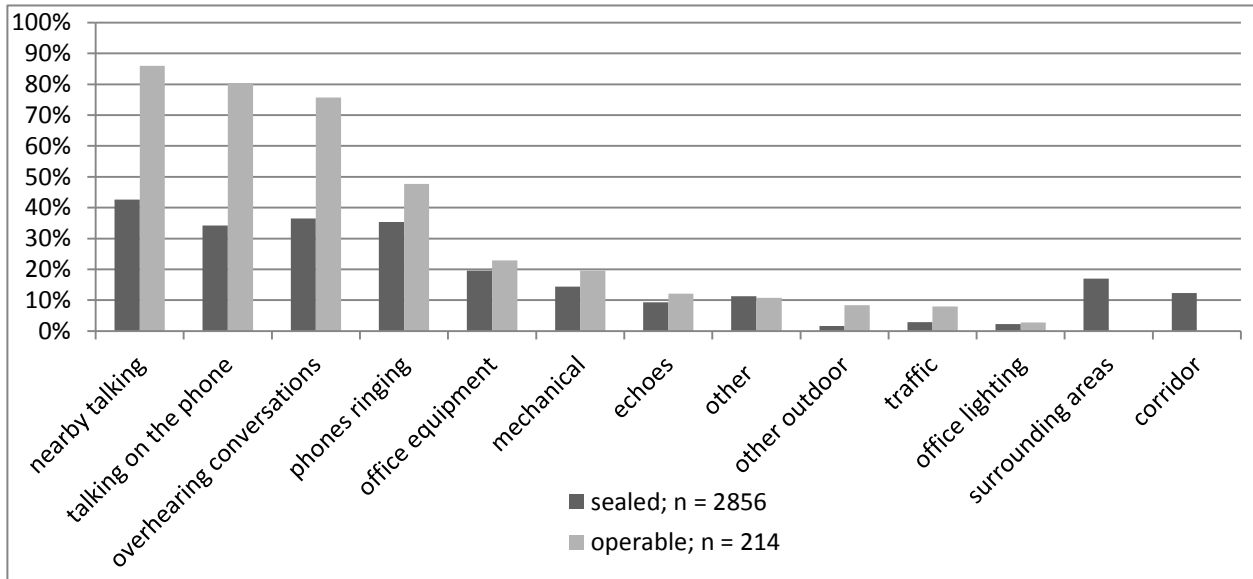


Figure 5. Interior (core) zone sources of noise dissatisfaction.

People that complain about phones ringing are likely to be among the occupants most dissatisfied with noise (Fig. 7). There is a mild correlation between noise satisfaction and phone ringing, which suggests that this kind of noise is extremely bothersome when present. It is noteworthy that traffic noise and other outdoor noise sources are towards the bottom of the list, suggesting that these are not extreme annoyances when they are present. Office workers experiencing outdoor noise might only be slightly dissatisfied whereas occupants experiencing phones ringing would be very dissatisfied.

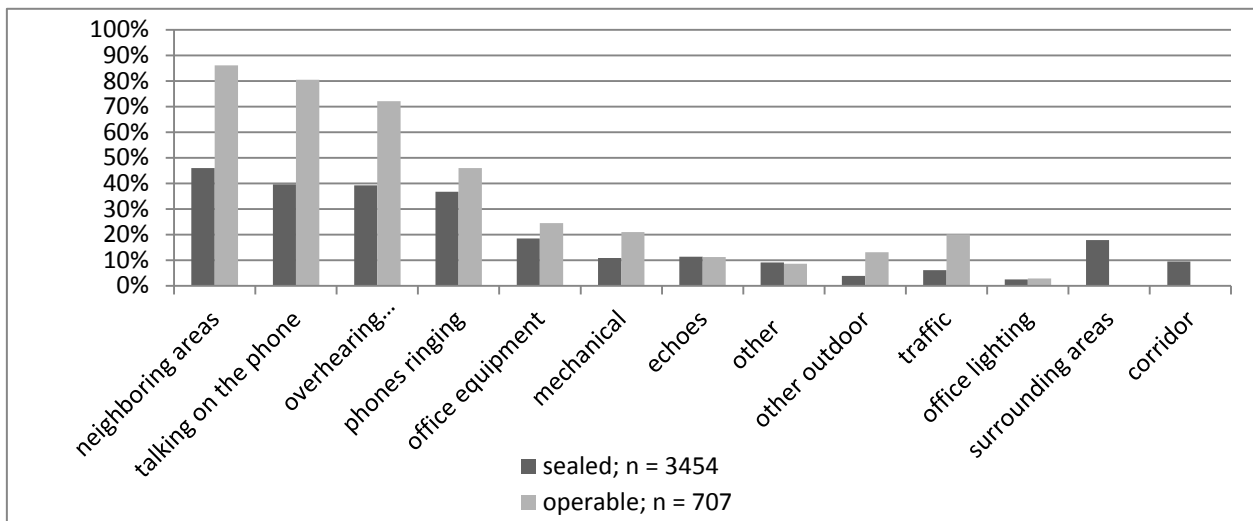


Figure 6 -- Near window sources of noise dissatisfaction

	Correlations	
ringing phones	-0.37	***
Talking nearby	-0.36	***
people talking on phones	-0.32	***
people in surrounding offices	-0.28	
office equipment noise	-0.27	**
talking in corridors	-0.23	***
people overhearing my conversations	-0.23	***
echoes	-0.19	
mechanical system noise	-0.19	*
other sources	-0.19	*
traffic noise	-0.13	***
other outdoor noise	-0.11	***
lighting noise	-0.09	***

Figure 7. Correlation of noise sources and satisfaction. (***, $p < .01$; **, $p < .05$; * $p < .1$).

Among outdoor noise sources of concern, the free text comments highlight that construction noise can be a significant problem when present (Fig. 8). It is the second most mentioned outdoor noise source with 37 occurrences among over 1,000 free-text comments about noise sources. It is however, very temporal and generally recedes with time. By far most text comments relate to physical features of the office or the design of individual workspaces.

responses	source
203	coworkers talking to each other
107	noise from phones or phone conversations
85	noise from coworkers walking
66	ineffective partitions/cubicles
59	music or radios
37	construction noise
32	noise from conference rooms
31	sound through walls
27	white noise is distracting
27	noise from cleaning crews
27	other outside noise (e.g. trains, motorcades, sirens, people outside)

Figure 8. Frequency of noise-related themes in text comments. 86% of comment categorized.

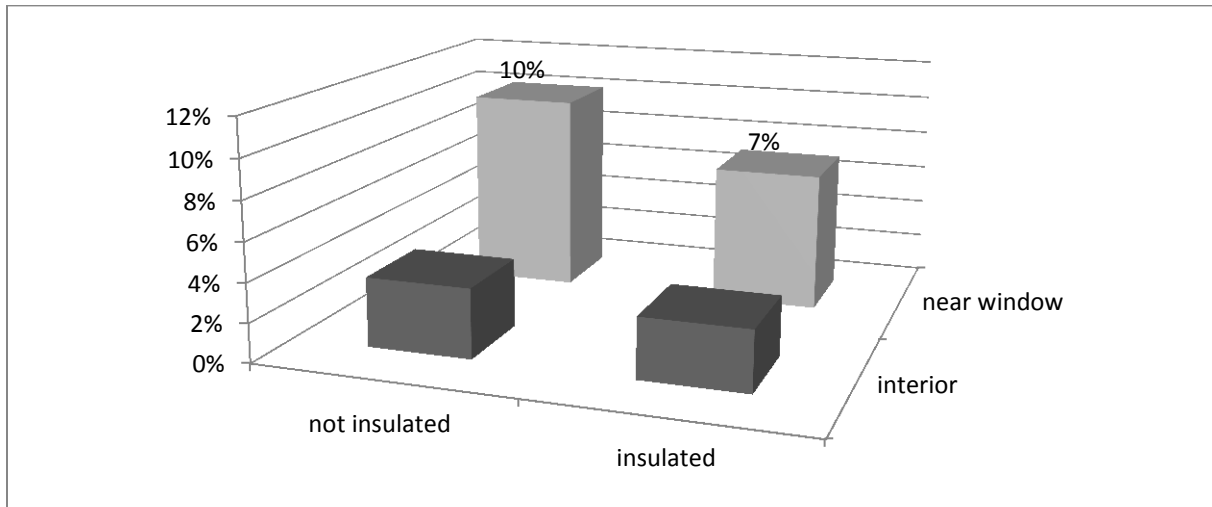


Figure 9. Dissatisfaction with traffic noise by distance to windows and insulated glass.

While there is only small dissatisfaction with outdoor noise, it is still worth considering what design elements might help attenuate dissatisfaction. There may be locations where outdoor noise is of special concern. For this reason, we consider traffic noise (the more problematic of the two outdoor sources) and the effect of insulated (double-pane) glass, window to wall ratio, and the floor on which the occupant sits, for occupants near windows for all buildings. We consider both operable and sealed buildings together here since it is likely that an occupant would close an operable window when outdoor noise is a problem. Thus, the sealed and operable building would have the same condition in this circumstance.

There is a small increase among those near windows that cite traffic (and other outdoor noise sources as problems in buildings without insulated glass (Fig. 9). This suggests that double-pane glass (or greater) may help attenuate dissatisfaction with outdoor noise to a small degree.

Floor	1	2	3	4	5	6	7	8	9	10
% satisfied	32%	32%	28%	29%	27%	27%	25%	25%	23%	25%

Figure 70. Percentage of occupants citing traffic noise dissatisfaction by floor.

There are also small differences in traffic noise dissatisfaction between floors (Fig. 10). The data show a constant decrease in traffic noise as a source of dissatisfaction as the floor number increases. This pattern holds for floors 1 through 9. Traffic noise dissatisfaction increases at floor 10 however. We did not have sufficient data to show statistically significant results after floor 10.

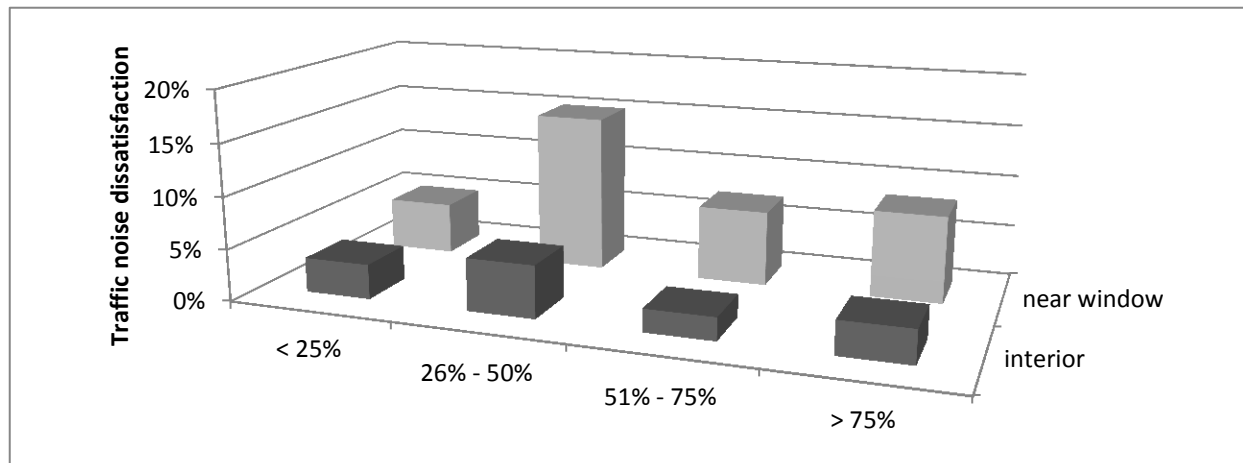


Figure 11. Percentage of occupants citing traffic noise dissatisfaction by window to wall ratio.

Buildings with a facade composed of 1/4 to 1/2 windows show the most traffic noise dissatisfaction. Strangely, buildings with more windows have less traffic noise issues reported (Fig. 11). This suggests that there is no relationship between window to wall ratio; some other building characteristic (a confounding variable) might be at play here.

Conclusion

These data suggest that outdoor is not a significant problem for office occupants as survey respondents near windows are more satisfied with noise than people without windows. Occupants near operable windows are the most satisfied overall. Among occupants dissatisfied with noise, indoor noise sources -- like people talking-- are about 10 times more prevalent in offices than outdoor noise. Among problematic noise sources, a phone ringing is most likely to create the strongest negative response.

Construction noise is of concern to occupants when present. The number of reports of problems with construction noise is small, but the comments are very passionate. For this reason, this noise source deserves special attention.

When outdoor noise is a problem, several options exist to attenuate dissatisfaction. Traffic noise complaints recede in the presence of double-pane windows and when occupants are on higher floors. This suggests that one way to respond to outdoor noise complaints is to move noise sensitive occupants to a higher floor or put them near windows with two or more panes of glass.

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