



## ACOUSTICAL QUALITY IN OFFICE WORKSTATIONS, AS ASSESSED BY OCCUPANT SURVEYS

KL Jensen<sup>1,\*</sup>, E Arens<sup>2</sup> and L Zagreus<sup>2</sup>

1 International Centre for Indoor Environment and Energy, Technical University of Denmark, Nils Koppels Alle, Building 402, DK-2800 Kgs. Lyngby, Denmark [www.ie.dtu.dk](http://www.ie.dtu.dk)

2 Center for the Built Environment, University of California Berkeley, USA

### ABSTRACT

We analyzed acoustic satisfaction in office environments in buildings surveyed by The Center For The Built Environment (CBE). A total of 23,450 respondents from 142 buildings were included in the analysis. Acoustic satisfaction in the CBE survey is a function of satisfaction with both noise and speech privacy. In the database people are significantly more dissatisfied with speech privacy than noise level ( $P < 0.01$ ). Occupants in private offices are significantly more satisfied with the acoustics than occupants in cubicles ( $P < 0.01$ ). The results shows also that occupants in open office environments are significantly more satisfied with noise level and speech privacy than occupants working in cubicles ( $P < 0.01$ ). Among occupants dissatisfied with acoustics the most prevalent problems are: "People talking on the phone", "People overhearing private conversations" and "People talking in surrounding offices". Over 50% of cubicle occupants think acoustics interfere with their ability to get their job done.

### INDEX TERMS

Noise, speech privacy, acoustic satisfaction, post occupancy evaluation (POE)

### INTRODUCTION

Acoustics are an important attribute of commercial office building design. Noise is probably the most prevalent annoyance source in offices, and can lead to increased stress for occupants (Evans et al. 2000, Sundstrom 1994). Speech privacy may be an even more important effect than noise (Sundstrom 1994). Yet acoustics in most cases do not receive the same level of design attention as thermal, ventilation and other architectural and engineering considerations (Salter et al. 2003). The causes and consequences of poor acoustical performance are perhaps not adequately understood by designers and building owners. It would therefore be valuable to determine from a large population of office buildings how occupants perceive their acoustical environments, and what aspects of office building design are influencing these perceptions.

The Center For The Built Environment (CBE) at UC Berkeley maintains an extensive post-occupancy-evaluation (POE) database for commercial buildings. The database contains results from CBE's web-based Occupant Indoor Environmental Quality (IEQ) survey, which has been used since 1996 to measure occupant response to buildings, diagnose the cause of problems, evaluate new building technologies, identify trends in performance, and benchmark the quality of individual buildings against the population of similar buildings. At the time of this study, 142 buildings had been surveyed in the USA, involving 23,450 occupants.

The survey includes modules for office layout, office furnishings, thermal comfort, air quality, lighting, acoustics and building cleanliness and maintenance. Each module is comprised of satisfaction-scale questions which branch to follow-up questions whenever dissatisfaction is indicated, to diagnose the causes of the dissatisfaction. The survey modules have been kept consistent over the years in order to accumulate the large, standardized database needed for benchmarking and trend analysis (Zagreus et al. 2003, 2004). The acoustics module of the database can be analyzed on its own, or examined for relationships to the building performance metrics in the other modules.

### RESEARCH METHODS

When respondents fill out the web-based Occupant IEQ survey, the data are saved in a Microsoft SQL Server 2000 database (Zagreus et al. 2004). The data for this study were imported from the SQL database into Microsoft Excel.

---

\* Corresponding author email: [klynge@privat.dk](mailto:klynge@privat.dk)

Here the data were cleaned and prepared for statistical analysis by the computer program Statistica.

The data can be divided up into subjective and objective variables. A subjective variable could be an occupant's satisfaction with the noise level or satisfaction with the sound-privacy level. The occupants vote on a 7-point satisfaction scale ranging from -3 to 3. Objective variables are demographic or other background data such as gender and office type. Physical factors relevant to the acoustic analysis such as phones ringing, people talking, noise from HVAC system etc, are also found in the branching drill-down questions that follow dissatisfied votes.

**Subjective variable data analysis**

The subjective analysis correlates the distribution of noise level or speech privacy votes with a particular aspect of the office environment, like office type (private office, shared office, cubicle with high partitions, cubicle with low partitions, or open office environment without partitions), and gender.

**Statistical analyses of the subjective variables**

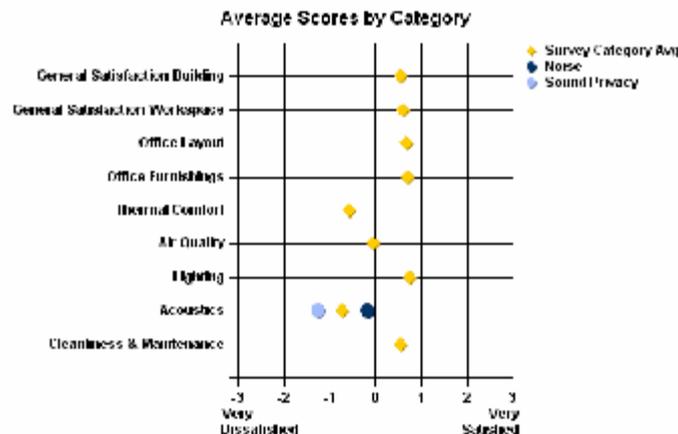
The P-values represent the probabilities that the Null Hypothesis is true; that there is no difference in the distribution of satisfaction with noise level or speech privacy caused by office types and gender. The P-values were calculated in Statistica using a non-parametric statistic, the Mann-Whitney U-test (Siegel et al. 1988). In this paper, we consider P-values less than 5% ( $P < 0.05$ ) to be statistically significant. To establish whether there is a statistically significant difference between the two acoustic satisfaction variables, the Wilcoxon Matched-Pairs Signed-Ranks Test is used (Siegel et al. 1988). The correlation coefficient for the two acoustic satisfaction questions is then calculated to determine how important noise-level satisfaction is when people are rating their sound-privacy satisfaction and vice versa.

**Objective variable data analysis**

The Occupant IEQ survey asks those respondents who have indicated dissatisfaction with noise level or speech privacy to identify problems contributing to this dissatisfaction on a follow-up page. The percentage of respondents indicating that a particular factor contributes to acoustic dissatisfaction is calculated based upon the number of respondents who saw the acoustic dissatisfaction follow-up questions.

**RESULTS**

The following results are based on data from a total of 142 buildings (total of 23450 respondents) from the CBE database. We did not include any instances where the survey had been repeated in a building, or buildings located outside USA. The acoustic quality category consistently receives the lowest average satisfaction score of the nine core satisfaction categories in the Occupant IEQ survey (Figure 1).



*Figure 1. Average scores for the nine core categories and the two acoustic satisfaction questions in the Occupant IEQ survey based on 23450 respondents*

The acoustic category score is calculated as an average of the satisfaction scores of two acoustic questions: satisfaction with noise level and satisfaction with speech privacy, (also shown in Figure 1). We can see that the low level of satisfaction with speech privacy reduces the average acoustic category score, so speech privacy dissatisfaction is largely responsible for the low average acoustic ratings.



If the data are divided up by office type, the difference between the two acoustic satisfaction questions is even clearer. Figure 2 shows the average of the two acoustic satisfaction scores.

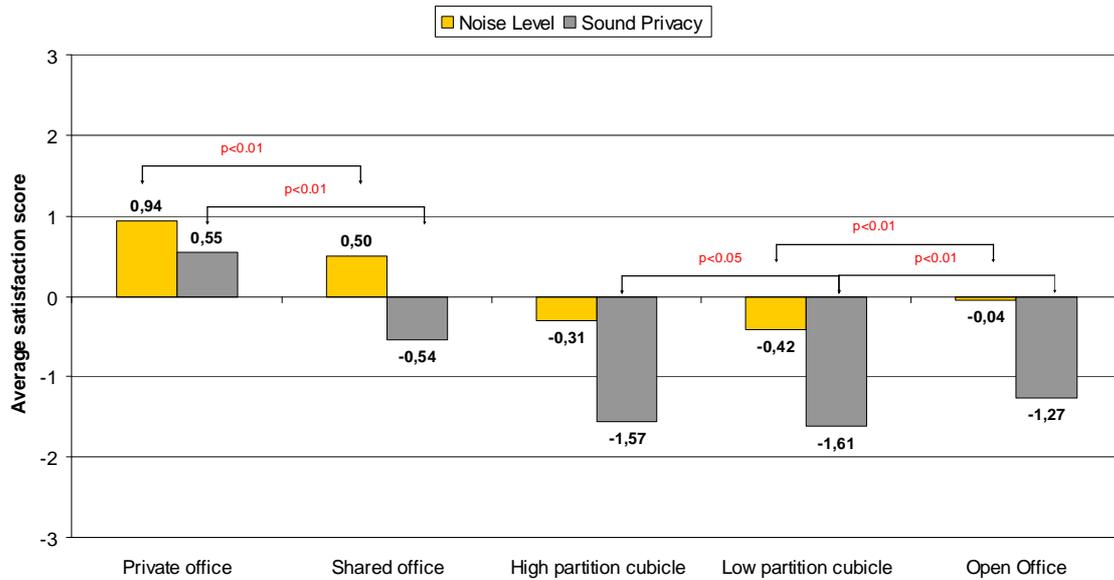


Figure 2. Average acoustic satisfaction score, by office type

The difference between private offices and cubicles in average acoustic satisfaction is clearly seen in Figure 2. Figure 2 also shows the big difference in satisfaction between the two acoustic questions. It is clear that there is a significant difference between all the different office-types (except between high and low cubicles regarding satisfaction with noise level). Clearly people are more dissatisfied with speech privacy than noise level. In cubicles with high or low partitions, both categories are negative with an average score for satisfaction with speech privacy of -1.57 and -1.61, respectively. People working in open office environments (without cubicle partitions) seem to be more satisfied with both noise and speech privacy than those in cubicles. The difference between the two categories (satisfaction with noise level and satisfaction with speech privacy) is statistically significant ( $P < 0.01$ ) in all types of offices.

The Occupant IEQ survey includes self-reported productivity questions in each survey category. For acoustics, the question is: "Overall, does the acoustic quality in your workspace enhance or interfere with your ability to get your job done?". Figure 3 shows this distribution for each office type.

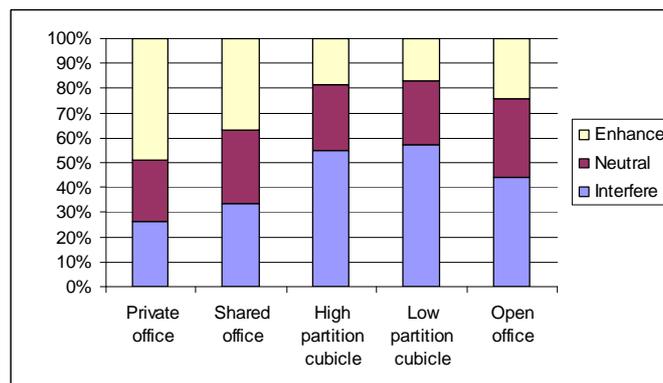


Figure 3. Percentage of occupants who indicate that acoustic quality either enhances, interferes or has a neutral effect on their ability to get their job done

We can see that over 50% of occupants in cubicles think that poor acoustics interfere with their daily work. Approximately 30% of occupants in private and shared offices also think that poor acoustics interfere with their ability to get their job done, but as many as 50% of these occupants regard their acoustical environment highly, saying that it enhances their ability to get their job done. It seems likely that such positive ratings reflect the



respondents' awareness of the alternatives to their private office acoustics (cubicle and open-office acoustics). Occupants in partitionless open offices think that acoustics interfere less with their work than do occupants in cubicles. This is consistent with their satisfaction ratings of these office types.

When survey respondents express dissatisfaction with acoustics, the survey presents them with a page of branching questions to allow them to identify specific causes of dissatisfaction. In Table 1 the percentages of occupants dissatisfied with a certain problem are listed, roughly in descending order of prevalence, divided by the different office types. The number of respondents (n) is the total number of respondents that had an opportunity to check that answer (i.e. those respondents who saw the branching questions).

**Table 1. Percentage of occupants dissatisfied with the acoustics, divided by specific causes**

	Private office	Shared office	Cubicles with high partitions	Cubicles with low partitions	Open office
People talking on the phone	64% (n=1698)	66% (n = 515)	81% (n = 5124)	82% (n = 2232)	64% (n=559)
People overhearing private conversations	59% (n=1698)	70% (n = 515)	82% (n = 5124)	82% (n = 2232)	76% (n=559)
People talking in surrounding offices	70% (n=2201)	59% (n = 722)	79% (n = 7198)	77% (n = 3016)	73% (n=617)
HVAC Noise	23% (n=2201)	21% (n=722)	18% (n = 7198)	20% (n = 3016)	25% (n=617)
Telephones ringing	23% (n=2201)	23% (n = 722)	37% (n = 7198)	38% (n = 3016)	34% (n=617)
Office equipment	19% (n=2201)	18% (n=722)	21% (n = 7198)	21% (n = 3016)	29% (n=617)

Table 3 shows that dissatisfaction priorities are almost the same in all office types, and that people are mostly dissatisfied with hearing other people talking on telephones, people overhearing private conversations, and the sound of people talking in surrounding offices.

**DISCUSSION**

The large difference between noise-level and speech-privacy satisfaction is significant. Several studies have examined the effect of noise level either as an individual parameter or a combination of one or more environmental parameters such as thermal load (Clausen et al. 1993, Pellerin et al. 2003, Witterseh et al. 2004). Witterseh et al.(2004) and other studies mention that irrelevant speak or intermittent noise (e.g. telephones ringing) have an effect of office workers performance and that it is the information content of the noise that causes distraction (Evans et al. 2000, Sundstrom 1994, Witterseh et al. 2004). Our data support these findings, in that the acoustic problem is mainly dissatisfaction with speech privacy and intermittent noise.

The specific causes identified for acoustic dissatisfaction also point toward dissatisfaction with speech privacy. For occupants in cubicles, over 80% have a problem with other people talking in telephones. Additionally, over 80% think it is a problem that other people can overhear their private conversations. In private offices and shared offices these two categories are considered a problem but the main problem is people talking from surrounding offices. This problem also exists in cubicles, with 79% and 77% dissatisfied in cubicles with high- and low partitions respectively. These categories could indicate that people get “caught up” in other occupant’s conversations. Irrelevant speech disrupts memory when task load is high, compared to noise at the same volume (Evans et al. 2000). This suggests solutions like sound masking to reduce speech intelligibility and covering room surfaces and partitions with sound-absorptive materials to reduce speech sound levels.

There is little difference between cubicles with high and low partitions in the problems that their occupants perceive as contributing to acoustic dissatisfaction. This suggests that acoustic satisfaction will not be improved by making cubicles higher. It should be noted that the height of the cubicle in the Occupant IEQ Survey is described as “above standing eye level” or “below standing eye level”, so a “high” partition can be somewhat different from person to person within a building depending on the person’s height. The biggest difference in acoustic satisfaction levels can be observed between private offices and cubicles. One solution could be to build private offices instead of cubicles, but if this solution is not economically feasible, there should be serious effort put into assuring that the acoustic conditions in the open plan offices are better than the current norm. One way might be through providing a varied overall workspace where tasks that require privacy or unusual concentration can be done in a few private rooms provided within the open-plan office. Another would be through sound masking or improving the acoustical properties of room and workstation surfaces. Salter et al.(2003) provide a method for predicting the level of speech privacy dissatisfaction and for designing workplaces that are acoustically satisfying. By accounting



for acoustic satisfaction in the design phase, some of the pervasive dissatisfaction revealed by this study might be averted.

Even though there is a big difference in acoustic satisfaction between private offices and cubicles, almost 30% of private office occupants also think that acoustics interfere with their ability to get their job done. This dissatisfaction is described in Salter et al. for occupant in private offices adjacent to conference rooms, or occupants in private offices near other private offices where people speak on speaker telephones.

An interesting finding is that occupants in totally open offices are significantly more satisfied with noise level and speech privacy level than occupants in cubicles, although cubicles are usually assumed to reduce the noise level experienced by their occupants. A possible explanation might be that private conversations are possible in open offices when a visual check reveals that there is nobody within earshot. Another might be that expectations for any form of privacy are lower in the visually open workplace, and that people adapt their listening and speaking habits accordingly.

### CONCLUSION AND IMPLICATIONS

- Ø Office workers are significantly more dissatisfied with the lack of speech privacy than with the level of noise.
- Ø Occupants in open office environments are more satisfied than the occupants of either type of cubicle with noise and speech privacy.
- Ø Overall, of the nine core satisfaction categories in the IEQ survey, poor acoustics cause the greatest dissatisfaction. This confirms findings from previous studies. More focus on ameliorating speech privacy and noise is needed to improve the well-being of occupants in open-plan office environments.

### ACKNOWLEDGEMENTS

We would like to thank Charlie Huizenga, CBE, and David Wyon, DTU, for their comments and technical assistance.

### REFERENCES

- Clausen G., Carrick L., Fanger P.O., Kim S.W., Poulsen T. and Rindel J.H.: *A Comparative Study of Discomfort caused by Indoor Air Pollution, Thermal load and Noise*, Indoor Air, Vol 3, 255-262, 1993
- Evans Gary W. and Johnson D.: *Stress and Open-Office Noise*, Journal of Applied Psychology, Vol 85, 5, 779-783, 2000
- Pellerin N. and Candas V.: *Effects of steady-state noise and temperature conditions on environmental perception and acceptability*, Indoor Air, Vol 14, 129-136, 2003
- Salter C., Powell K., Begault D. and Alavarado R.: *Case studies of a method for predicting speech privacy in the contemporary workplace*, Center For The Built Environment, UC Berkeley, January 2003
- Siegel S., Castellan N. and John J.R.: *Nonparametric Statistic for the behavioral sciences*, second edition, McGraw-Hill, New York, 1988
- Sundstrom E., Town J.P., Rice R.W., Osborn D.P. and Brill M.: *Office noise, satisfaction and performance*, Environment and Behavior, Vol 26, No. 2, 195-222, March 1994
- Witterseh T., Wyon D.P. and Clausen G.: *The effects of moderate heat stress and open-plan office noise distraction on SBS symptoms and on the performance of office work*, Indoor Air, Vol 14 (Suppl 8), 30-40, 2004
- Zagreus L. and Huizenga C.: *Using the CBE Occupant survey to assess facility management performance in GSA facilities*, summary report, Center For the Built Environment, UC Berkeley, August 2003
- Zagreus L., Huizenga C., Arens E. and Lehrer D.: *Listening to the occupants: a Web-based indoor environmental quality survey*, Indoor Air, Vol 14 (Suppl 8), 65-74, 2004