

Perceived acoustic environment, work performance and well-being - survey results from Finnish offices

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ABSTRACT

The aim of the study was to investigate workers' perceptions of the acoustic environment of offices and study its relations to work performance and well-being. Questionnaire results from 11 companies and 689 respondents were analyzed. Occupants in private rooms and open offices were compared. Noise was the main indoor environmental problem in open offices. Speech was the most distracting source of noise in both office types but the degree of disturbance was lower in private rooms. About half of open office occupants and 20 % of occupants in private rooms were dissatisfied with acoustics. Office noise disturbed particularly conversations and tasks relying on working memory and verbal processes, such as text comprehension and creative thinking. Routine tasks were little disturbed by noise. In open offices, attempts to cope with noise reflected risk factors to individual productivity and well-being, such as taking extra breaks, compromising the quality of work, working overtime and exerting oneself harder. Self-estimated waste of daily working time due to noise was twofold in open offices. Open office workers experienced more stress symptoms, particularly overstrain and difficulties in concentration, and attributed these symptoms to office noise to a greater extent than workers in private rooms. Possibilities to influence issues related to one's work and work-space privacy were lower among open office occupants. The results suggests that private rooms are superior to open offices in all respects.

INTRODUCTION

There is an increasing worldwide trend to build open offices instead of private room offices. Open offices are preferred because of better space economy, spaciousness and flexibility. Open offices are also assumed to facilitate teamwork and information sharing. However, there is continuous debate on the positive and negative effects of open offices on work performance and well-being. According to a meta-analysis carried out by DeCroon et al. (2005), there is strong evidence that working in open offices reduces worker's psychological privacy and job satisfaction. Some evidence exists that cognitive workload increases in open offices.

Cross-sectional office surveys that have compared different office lay-outs, e.g. Becker et al. (1983), Danielsson (2005), Pejtersen et al. (2006) and Jensen et al. (2005), have shown that the most severe factor causing office dissatisfaction is noise. Danielsson (2005) compared several office lay-outs and concluded that dissatisfaction with noise and privacy was highest in large open offices and lowest in cellular offices. Pejtersen et al. (2006) found that the percentage of occupants complaining about noise was ten-fold in large open offices compared to cellular offices. The same study demonstrated an association between office size and several symptoms, including fatigue, headache and difficulties in concentration. Open office occupants

have also reported more subjective performance loss due to noise than cellular office workers, e.g. in the amount of accomplished work (Becker et al. 1983).

The present study aims to improve the general understanding of open office conditions and its effects on work performance and worker well-being. This is done by using a questionnaire method that addresses a wide range of issues related to noise disturbance, its effects on work and workers and the functional performance of office lay-out. Open office conditions are compared to conditions in private offices. This paper continues the work of Helenius et al. (2007) using to large extent the same material.

METHODS

Subjects

A total of 689 subjects from 11 office buildings took part in the study. In addition, there were 60 respondents occupying shared offices of 2 to 4 people but their results are not reported in this paper. Data was gathered between 2002 and 2008. Background information of the data is presented in Table 1. The acoustical conditions of the office buildings represented typical Finnish offices built after 1990. Seven of the studied companies had a combination of private rooms and open offices while three companies had mainly open offices and one had only private rooms. The number of respondents varied between 13 and 196 in different companies. Different lines of business were included in the sample. The survey always targeted all workers of a department participating in the study so the workers represented a wide range of professions not enumerated here.

Table 1: Background information

	Number of respondents		Age in years Range (mean)	Female %	Male %
	Private room	Open office			
Sample A	93	260	19-65 (44,4)	36,8	63,2
Sample B	88	248	20-65 (40,9)	63,4	36,6
Full sample	181	508	19-65 (42,7)	49,7	50,3

Questionnaire

An office acoustics questionnaire was developed on the basis of a literature review and a pilot study. The questionnaire had several sections. *Indoor environment* and *Noise sources* covered the disturbance of indoor environmental factors in general, the disturbance of specific noise sources, satisfaction with work environment and acoustic satisfaction. *Noise effects* covered the disturbance of different work tasks, behavioral efforts to cope with noise and self-estimated waste of daily working time due to noise. *Well-being* covered general stress symptoms and symptoms attributed to office noise. *Psychosocial environment* covered psychosocial stress factors, e.g. job satisfaction and hurry at work. *Office lay-out performance* assessed quality of teamwork and communication, privacy, comfort and availability of practical resources in the office area. *Work space preference* was also inquired with one question. Most questions were answered on a 5-point Likert scale. Individual factors, e.g. noise sensitivity, were also assessed but are not reported in this paper.

Some modifications were made to the questionnaire during the research period and some companies did not allow all sections to be included, e.g. questions about the

psychosocial issues. Therefore, the number of respondents varies in different questions and is reported separately for each analysis. In the sections *Indoor Environment* and *Noise Sources* the data from all companies could not be combined because of a change in the phrasing of the question: in half of the offices (Sample A), respondents were asked to rate *how often* they were disturbed whereas the other half (Sample B) rated *how much* they were disturbed. Asking about frequency instead of degree of disturbance resulted in higher estimates of distraction and some of the differences were statistically significant. Data was therefore analyzed separately for the two subsamples in these specific sections.

RESULTS

The data was analyzed with SPSS 16.0 statistical program. The comparisons between open offices and private rooms were performed using Mann-Whitney U-test.

Indoor environment. Noise was the main indoor environmental problem in open offices in both samples. Open office occupants were significantly more disturbed by noise than workers in private rooms. Open office occupants also complained more about other indoor environment factors than did workers in private rooms. The disturbance of indoor environment factors was similar in both subsamples and only the subsample focusing on the frequency of disturbance is reported in Table 2. Disturbance caused by noise is reported for both samples.

Table 2: The average disturbance of indoor environment factors. Scale 1-5, with 1 indicating no disturbance and 5 indicating highest level of disturbance. Subsample A rated the frequency of disturbance while subsample B rated the degree of disturbance.

	Sub-sample	N	Items	Cronbach's alpha	Mean (SD)		P-value
					Private room	Open office	
Thermal conditions	A	344	2	0,683	2,11 (0,89)	2,40 (0,98)	0,016
Air quality	A	346	4	0,800	1,93 (0,79)	2,19 (0,80)	0,007
Noise	A	346	1	-	2,45 (0,97)	3,55 (1,16)	0,000
	B	335	1	-	2,50 (0,97)	3,29 (1,05)	0,000
Lighting (amount of light and glare)	A	352	1	-	2,12 (0,98)	2,51 (1,12)	0,004

Noise sources. Results for the Sample A focusing on the frequency of disturbance of sounds are shown in Table 3. The most distracting sound sources in open offices were speech near one's work station and sounds of phones ringing. Speech also disturbed private room occupants the most but not to the same extent. The pattern of disturbance from different sounds was similar in Samples A and B, except that in Sample B open office occupants were less disturbed by ventilation noise ($p < .01$) than private room occupants.

Satisfaction with the indoor environment as a whole and acoustic satisfaction were lower among open office occupants (Table 4). Fifty percent of open office occupants were dissatisfied with acoustics at their work station while only 21 percent of private rooms occupants were dissatisfied.

Table 3: The disturbance to concentration caused by different noise sources. The table shows mean values for Sample A on the scale from 1 (never disturbs) to 5 (disturbs very often); standard deviations in brackets.

	N	Mean (SD)		P-value
		Private room	Open office	
Speech in open office (near one's desk)	244	not relevant	3,40 (1,24)	
Speech from adjacent rooms	221	2,33 (1,08)	2,02 (1,16)	0,009
Speech from common facilities, e.g. coffee rooms	335	1,83 (1,04)	2,33 (1,27)	0,001
Ventilation noise	335	1,56 (0,85)	2,03 (1,15)	0,000
Own pc	335	1,44 (0,74)	1,57 (0,78)	ns
Office equipment	337	1,45 (0,77)	2,15 (1,07)	0,000
Phones ringing	335	1,97 (0,85)	3,05 (1,13)	0,000
Radio, music	337	1,30 (0,64)	1,54 (0,72)	0,002
Traffic on corridors, doors, elevator	336	2,03 (0,95)	2,58 (1,24)	0,000
Construction work, reparations	336	1,63 (0,76)	1,74 (0,71)	ns
Sounds made by others working	333	1,25 (0,46)	2,08 (1,13)	0,000
Environmental noise from outside	335	1,44 (0,67)	1,34 (0,53)	ns

Table 4: Satisfaction with work environment as a whole (n=422) and satisfaction with acoustics at one's work station (n=464). Outermost classes are combined in the table but statistical tests were conducted using original distributions. Percentages within office types are shown.

	Satisfaction with work environment ($p < .001$)		Satisfaction with acoustics ($p < .001$)	
	Private room	Open office	Private room	Open office
very or somewhat dissatisfied	9,3	30,4	21,1	50,0
neutral	14,7	20,8	21,1	21,4
very or somewhat satisfied	76,0	48,8	57,9	28,6

Table 5: Disturbance of different types of tasks due to workplace noise. The table shows mean values for disturbance on the scale from 1 (not at all disturbed) to 5 (very much disturbed).

	N	Items	Cronbach's alpha	Private room Mean (SD)	Open office Mean (SD)	P-value
Conversations	653	2	0,834	2,12 (1,01)	2,78 (1,15)	0,000
Complex verbal tasks	622	2	0,754	2,46 (1,02)	2,78 (1,19)	0,003
Routine work	593	1	-	1,35 (0,69)	1,45 (0,76)	ns
Arithmetic tasks	560	1	-	2,02 (1,02)	2,23 (1,28)	ns

Noise effects. Conversations and complex verbal tasks, such as text processing and planning, were more disturbed by noise in open offices than in private rooms (Table 5). Routine work and arithmetic tasks were less affected and the degree of disturbance did not differ between the office types. Self-estimated waste of daily working time due to noise was higher in open offices (Table 6).

Behavioral efforts to cope with noise took place more often in open offices than in private rooms (Table 7). These included taking extra breaks, exerting one-self harder,

working overtime and doing remote work. Quality of work was also more often compromised in open offices in order to cope with noise. Compromising quality of work correlated with overall coping ($r = .702, p < .01$) but it was left out of the sum variable because of a lower number of respondents.

Table 6: Self-estimated waste of daily working time due to noise in minutes

	N	Private room Mean (SD)	Open office Mean (SD)	P-value
Wasted working time	615	12,00 (15,00)	21,48 (20,11)	0,000

Table 7: Behavioral coping efforts and stress symptoms on a scale from 1 to 5 (1 indicating no symptoms/coping and 5 indicating very much symptoms/coping)

	N	Items	Cronbach's alpha	Private room Mean (SD)	Open office Mean (SD)	P-value
Coping efforts	581	4	0,840	1,76 (0,64)	2,14 (0,81)	0,000
Compromising quality of work	444	1	-	1,43 (0,69)	1,85 (1,02)	0,000
Stress symptoms	380	4	0,890	2,27 (0,75)	2,64 (0,95)	0,000

Well-being. Overall stress was higher among open office workers (Table 7). Separate analyses of each symptom showed that particularly difficulties in concentration were more prevalent among open office occupants (Table 8). Workers in open offices also experienced more tiredness and exhaustion. Irritation and motivational difficulties seemed to be more prevalent among open office occupants but the difference failed to reach statistical significance.

Table 8: Prevalence of stress symptoms and the percentage of occupants attributing symptoms to noise. Prevalence of symptoms was evaluated on a scale from 1 (not at all) to 5 (very much). Percentage of noise-related symptoms is calculated for the population expressing little or more symptoms (values 2-5 in the symptom prevalence question).

	N	Prevalence of symptom, mean (SD)		P-value	Occupants attributing symptom to noise, %		P-value
		Private	Open		Private	Open	
Irritation	476	2,36 (0,88)	2,58 (1,10)	0,058	16,3	48,6	0,000
Tiredness or exhaustion	450	2,60 (0,93)	2,91 (1,05)	0,008	9,3	42,1	0,000
Difficulties in concentration	475	2,24 (0,94)	2,69 (1,16)	0,000	23,0	56,3	0,000
Motivational difficulties	407	2,19 (1,01)	2,41 (1,12)	0,064	10,7	28,2	0,000

Percentage of occupants attributing symptoms to office noise was calculated for the population that indicated having symptoms (values 2 'little' to 5 'very much'). About 87 percent of private room occupants and 82 percent of open office occupants belonged to this group. Those who indicated that their symptoms might be due to office noise 'to some degree' or more (values 3 to 5) were considered to attribute the symptom to noise. Those respondents whose symptoms were 'little' or 'not at all' due to noise (values 1 to 2) were considered not to have noise-related symptoms. The results show that open office occupants attributed symptoms to office noise to a greater extent than private office occupants.

Psychosocial environment. Most psychosocial stress factors did not differ between the office types (Table 9). Open office occupants received more support from co-workers or managers than did workers in private offices. This may also reflect the content of work as it is likely that workers with private offices have more independent job descriptions, and therefore, less need for support. Possibilities to influence issues related to one's work were perceived lower among open office occupants.

Table 9: Psychosocial stress factors. Scale 1= not at all, 5= very much

	N	Private room Mean (SD)	Open office Mean (SD)	P-value
Hurry at work	392	3,48 (0,85)	3,43 (0,90)	ns
Work feels interesting and inspiring	336	3,66 (0,90)	3,61 (0,93)	ns
Mental strain experienced at work	444	3,33 (0,80)	3,25 (0,90)	ns
Support received from co-workers or manager	248	3,25 (0,94)	3,54 (0,81)	0,015
Possibilities to influence one's work	303	3,26 (0,95)	2,88 (0,96)	0,003
Job satisfaction	380	3,82 (0,68)	3,71 (0,82)	ns

Functional performance of the office lay-out. Open office occupants experienced lower privacy in their work area than private room occupants (Table 10). Less practical resources, such as work space and meeting facilities, were perceived to be available in open offices. Comfort was assessed more negatively in open offices than in private offices. Contrary to expectations, the quality of teamwork and communication did not differ between open offices and private offices. In fact, the mean values for the quality of communication are nearly identical. The sum variable for teamwork included statements such as, 'colleagues are within easy reach', 'information is shared well between colleagues' and 'collaboration is effective'.

Table 10: Functional performance of the office lay-out. Factors have been assessed on a scale from 1 to 5, with '1' indicating most negative assessment and '5' most positive

	N	Items	Cronbach's alpha	Private room Mean (SD)	Open office Mean (SD)	P-value
Privacy	492	2	0,888	3,83 (0,78)	2,34 (1,04)	0,000
Teamwork and communication	490	4	0,845	3,75 (0,62)	3,74 (0,73)	ns
Availability of practical resources	489	3	0,714	3,77 (0,74)	3,37 (0,84)	0,000
Comfort	489	2	0,776	3,33 (0,74)	2,66 (0,95)	0,000

Work space preference. Results for work space preference are shown in Table 11. The results show that 21 percent of open office occupants prefer working in open offices and 33 percent would choose a shared office.

Table 11: Workspace preference in percentages for open office and private room occupants (N=569)

Work space at present	Preferred work space		
	Private room	Shared office of 2 to 4 persons	Open office
Private room	97,6	0,6	1,8
Open office	46,9	32,6	20,5

DISCUSSION

The results suggest that open offices have versatile acoustic problems in terms of subjective disturbance, performance effects and worker well-being. The expected benefits of open offices regarding functional efficiency were not supported by the results. Modern office work is increasingly characterized by cognitively demanding tasks in which background noise is perceived as particularly disturbing. The study gives no support to an extensive preference of open offices when workers' well-being and efficiency are of main concern.

Objective measurement of performance effects of noise is very difficult in real offices. In this study, subjective evaluations of wasted working time due to noise were higher in open offices than in private rooms, providing one measure for the performance effects of noise. The estimates of lost minutes cannot be regarded as exact in objective terms but the finding that workers change their behavior to cope with noise supports the conclusion that working time is indeed wasted because of noise. For example, open office occupants reported taking extra breaks and rescheduling work due to workplace noise.

Open office occupants suffered more from difficulties in concentration and tiredness. In open offices, a greater percentage of those suffering from symptoms attributed symptoms to office noise. It seems unlikely that the higher stress levels among open office occupants were due to differences in psychosocial work environments as these factors were mostly assessed similarly in open and private offices. Our results are in line with the view that open office conditions and the accompanying lack of privacy form an extra stress factor to an individual worker. Further analyses will be conducted with the data to address the relations between office type, stress, indoor environment and psychosocial environment in more depth.

The results contradict the most common assumption of the benefits of open office layouts, that is, facilitation of communication and co-operation. The quality of teamwork and communication did not differ between open offices and private rooms at all. However, it is likely that in most of the studied open offices the respondents' work was characterized mainly by individual performance in which constant availability of colleagues and information exchange is not necessary. Open offices may be suitable for specific jobs that are mainly comprised of teamwork.

The study does not suggest that open offices should not be used. Twenty-one percent of open office workers preferred open offices to other office types. Although evidence could not be presented in this study, it is probable that many of these persons have a continuous need for communication with colleagues. The main problem seems to be that the selection of occupant's workstation is not based on the analysis of job demands. As periods of individual work and telephone conversations are still predominant in most office professions, open offices do not provide sufficient acoustic, visual and psychological privacy for typical office work.

Future studies should include a more detailed analysis of the job type of open office workers and a more detailed analysis of the open office type. There are very large differences in the size of open offices, in the facilities available to workers and also in the flexibility of workstations which were not considered in this study. It is very important to be able to develop instructions for designing most appropriate work environments.

Acoustic conditions in the open offices can vary significantly. Hongisto et al. (2007) have shown that in good offices, the distraction of speech restricts to 5 meters from

the speaker while in worst offices, the speech distracts up to 20 meters from the speaker. The acoustic quality of open offices should also be measured in future surveys to show how acoustic problems depend on acoustic design.

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