Noise effect on comfort in open-space offices: development of an assessment questionnaire

Marjorie Pierrette, Etienne Parizet, P. Chevret, J. Chatillon

Noise effect on comfort in open-space offices: development of an assessment questionnaire

M. Pierrette [a)*], E. Parizet[a)], P. Chevret [b)], J. Chatillon[b)]

[a)] Laboratoire Vibrations Acoustique, INSA, Lyon, France. [b)] Institut National de Recherche et de Sécurité, Vandœuvre-lès-Nancy, France.

*Corresponding author: marjorie.pierrette@gmail.com

Abstract

It is currently accepted that noise is one of the most important annoyance factors in open-space offices. However, noise levels measured on open spaces of the tertiary sector rarely exceed 65 dB(A). It therefore appears necessary to develop a tool that can be used to assess the noise environment of these offices and identify the parameters to be taken into consideration when assessing the noise annoyance. This paper presents a questionnaire to be filled by people working in such environment, and a case study in different open plan offices. The majority of the 237 respondents consider that the ambient noise level in their environment is high and that intelligible conversations between their colleagues represent the main source of noise annoyance. This annoyance was significantly correlated with their evaluation of sound intensity, which could not be represented by A-weighted level measurements.

Practitioner summary

This paper presents a short questionnaire aimed to evaluate the employees' comfort in an open-plan office and to propose optimal modifications of the office. Answers collected from 237 respondents showed that intelligible conversations represent the main source of noise annoyance; moreover, overall noise level is not related to this annoyance.

1. Introduction

The modern open-space concept was developed by two German consultants, the brothers Eberhard and Wolfgang Schnelle, in the 1950s. This type of partitionless office layout found considerable success in the United States and has become much more widespread in Europe since 1980. Most companies have now adopted this type of work space (according to a survey conducted in 2008, 60 % French companies use open-space offices), in all business sectors. There is no specific definition or size of the open-space office and the layout of these work spaces depends on the individual companies (Bodin Danielsson & Bodin, 2008). They may be simple collective offices or completely open platforms accommodating several dozen employees. The intention of these open-space offices is to improve communication between colleagues and therefore facilitate team or project work, save space and be closer to the managers. Employees nevertheless often complain that they permanently feel spied upon (e.g. *"L'open space m'a tuer"* (Open-space killed me) by Alexandre des Isnards & Thomas Zuber, 2008) and that they suffer from a high level of ambient noise (noise annoyance related to the work of the other employees and the equipment).

According to one highly exhaustive survey conducted in 2010 by the Haute Ecole de Lucerne on behalf of the Swiss State Secretariat for the Economy (SBiB, 2010), noise is one of the main annoyance factors in open spaces. This survey agrees with several studies which demonstrated that the acoustic environment was considerably less satisfactory in open-space offices than in private offices (e.g. Nemecek & Grandjean, 1973; Sundstrom *et al.*, 1994; de Croon *et al.*, 2005; Kaarlela-Tuomala *et al.*, 2009). For example, Kaarlela-Tuomala *et al.* (2009) studied employees who moved from a private office to an open space. The study highlights the negative effects of open space on 31 employees interviewed before and after the move. The sound level increased significantly and resulted in more disruptions during work, the feeling of privacy decreased, concentration difficulties increased. This study also demonstrates a lack of the beneficial effects generally associated with open-space offices: cooperation becomes less pleasant and the circulation of information is unchanged. The researchers conclude that work in open space is not recommended.

Numerous laboratory experiments have demonstrated that noise in offices has a disrupting effect on cognitive performance, such as mental arithmetic (e.g. Banbury & Berry, 1998), learning of associated words or a text (e.g. LeCompte, 1994; Banbury & Berry, 1998), counting points displayed visually (e.g. Buchner *et al.*, 1998), correction tasks (e.g. Jones *et al.*, 1990), understanding text and recall (e.g. Knez & Hygge, 2002; Oswald *et al.*, 2000).

Noise in the work place would also appear to affect physical and mental health. Several researchers (Pejtersen *et al.*, 2006; Haapakangas *et al.*, 2008) have stressed the importance of noise on health by comparing the declared health of people working in an open office and that of people working in a private office. They found that the percentage of occupants complaining about noise was ten times greater in large open spaces than in private offices. The same study demonstrated an association between office size and several symptoms including headache, fatigue and difficulties in concentration. Open office occupants consider that they need to make significantly more cognitive efforts and have more symptoms related to stress than persons working in private offices. They also feel more tired and more exhausted, though contradictory results can be found in the literature. As an example, Meijer *et al.* (2009) noticed no long-term fatigue effects due to open plan office arrangement. But Bodin Danielsson *et al.*(2013) show, in a recent research, a higher 12-month prevalence of short sick leave spells among employees in open-plan offices. Marmot *et al.* (2006) nevertheless observed that persons able to adjust the environmental factors themselves (light, temperature) suffered less from SBS (sick building syndrome) than those who are unable to influence their environment.

Currently in France, standard NF EN ISO 3382-3, 2012 specifies the method used to measure the acoustic properties of open-space offices with furniture. This standard takes into account the factors influencing the acoustic performance of open-space offices such as furniture layout, acoustic absorption and background noise. It does not take into account, however, how the employees themselves perceive their workplace noise environment, while studies on the assessment of noise in general have demonstrated that the perceived intensity only accounted for 20 % (Job, 1996) to 25 % (Landström *et al.*, 1995) of the variance in noise annoyance felt by the individuals.

The various studies conducted on the perception of noise in open-space offices emphasise that other factors must be taken into account when assessing the noise annoyance: the noise source(s), the task to be performed, personal sensitivity to noise, working environment. The effect of these factors will be exposed in the following.

Noise source

Removal of partitions in the work space generates numerous noise sources: phones ringing, people speaking on the telephone, people speaking to each other, computer keyboards, office equipment, musical ambience or background noise, ventilation or air-conditioning system, noise outside the building, etc. (SBiB, 2010). It would appear that the noise sources present in open-space offices are not all perceived in the same way and do not have the same impact on

the annoyance felt. Several studies have confirmed in particular that noises considered as controllable and/or useful are less disturbing than noises considered to be uncontrollable and/or unnecessary (Banbury & Berry, 2005; Haapakangas *et al.*, 2008; Kaarlela-Tuomaala *et al.*, 2009; Sailer *et al.*, 2000; Sundstrom *et al.*, 1994). Similarly, a continuous noise such as that of the ventilation is generally considered as causing little annoyance. It is in fact easier to get used to a constant noise than to a variable noise (Kjellberg *et al.*, 1996). According to these various studies, it seems that the noises considered most annoying and most disturbing for work are telephones ringing (more specifically those ringing in empty offices) and conversations (on the phone or between colleagues). Several studies indicate that the disturbance generated by conversation is largely due to the quality of speech transmission. Hongisto (2005) puts forward a model describing the disturbance in cognitive tasks according to a Speech Transmission Index (STI). To assess this model, Haka *et al.* (2009) tested the impact of three STI levels on various cognitive tasks (2 verbal recall tasks, 1 visuospatial memorisation task, 2 verbal tasks based largely on semantics). This study demonstrated poorer performance between an STI of 0.65 and an STI of 0.10 or 0.35. However, they found no significant difference between 0.35 and 0.10. These results agree with the studies conducted by Jones and Macken (1995) who demonstrated, through several laboratory experiments, that the number of errors on a short memorisation task decreases with the number of voices present during the task, i.e. when the STI decreases. The results are less good in the presence of one or two voices than in the presence of six voices. The speech level, the content and orientation of the source vary continuously, making it impossible to get used to the speech. Moreover, it has been found that reactions to noise largely depend on the nature of the task to be performed (Beaman, 2005).

Task

Kjellberg and Sköldström (1991) conducted a series of experiments with different more or less simple tasks (a simple and complex reaction time task, a proofreading task and a grammatical reasoning task (GRT)). They reported that the level of annoyance due to noise increases with the difficulty of the task. The disturbance is greater for the grammatical reasoning task than for a reaction time task. Haka et *al.* (2009) indicate that a visuospatial memorisation task is not disturbed by the presence of speech. Baddeley (2000) explains this result by the fact that auditory information does not interfere with visual information (different coders are used).

Noise sensitivity

Individual factors may also explain the level of noise annoyance. Studies conducted on the annoyance level attributed to noise (Moch & Maramotti, 1995) indicate that the sensitivity level estimated by the respondents themselves is related to the perceived annoyance level. The most sensitive subjects claim that they are more exposed than the others and therefore more annoyed. According to a study conducted by Job (1988), noise sensitivity would be highly correlated with the subjective reactions to noise. It would explain approximately 9% of the variance in reaction. In a study conducted in 1998, Miedema and Vos reported that the difference in noise annoyance expressed between persons with low and high sound sensitivity was equal to the difference caused by a variation of 11 dB in the sound exposure.

Working environment

Some factors, not necessarily related to the sound aspect of the offices, may also be expressed in terms of perceived noise annoyance. It has been demonstrated that when employees consider that they are working in a satisfactory environment, they tend to attribute this satisfaction to their work, considering that a work situation is satisfactory when the work itself is satisfactory. On the contrary, when the work is considered unsatisfactory, the physical environment is in turn perceived negatively and, in this case, the individuals tend to see it as the source of their dissatisfaction (Fischer, 1989). Similarly, it seems important to understand how the physical comfort aspects are assessed by employees (visual comfort, thermal comfort, acoustic comfort) since each one may have an impact on the other. Sundstrom and Sundstrom (1986) demonstrated that assessment of comfort is subjective and that assessment of thermal comfort, for example, may be related to other factors such as noise. Haapakangas *et al.* (2008) also emphasised that persons working in open spaces consider the acoustic quality, as well as the thermal quality, lighting and air quality, of the offices to be significantly lower. Lee and Brand (2005) studied how assessment of the working environment and job satisfaction depend on the work space layout. They measured that the more the respondents claim to be satisfied with their working environment, the less they perceive distractions. Lee and Brand (2010) also showed that if employees can control their office work environment, this reduces the distraction. Huang *et al.*, (2004) demonstrate the importance of the ergonomic aspect in the workplace on improving the efficiency, perceived control and environmental satisfaction. The findings of their study indicate that environmental control is significantly and positively related to environmental satisfaction.

All these factors emphasise the importance of subjectivity of noise assessment by the employees and the need to develop a tool to record the various parameters to be taken into account when assessing noise annoyance in open-space offices. No tool capable of

considering both the noise environment as perceived by employees and the consequences of this environment is currently available. The aim of this study is therefore to develop an efficient tool designed to assess how employees perceive their workplace noise environment, identify factors likely to influence this assessment and measure the impact of this environment on work and health. A questionnaire has therefore been drawn up and proposed to employees from several companies working in open-space offices. The results obtained are provided in the third section *"application case"*.

2. Drawing up the questionnaire

The questionnaire was drawn up using all the information collected during the bibliographic search and during several semi-directive interviews. It consists of 67 questions grouped in four sections structured around an assessment of the employees' physical working environment, a more specific approach of the noise environment and an assessment of the consequences of this environment on the employees' health. The questionnaire is included in appendix.

In the first section of the questionnaire, "General information about yourself and your workstation", data such as sex, age, seniority in the company, seniority in the current job and number of persons working in the same work space are collected. This first section also allows us to assess the employees' satisfaction with their physical working environment. Satisfaction regarding the physical working environment is assessed using a scale developed by Fleury-Bahi and Marcouyeux (2011). The scale, consisting of 14 items, measures satisfaction regarding the work space according to two dimensions: Control/Privacy (7 items) and Comfort/Functionality (7 items). For example, "*Possibilities available to manage noise*" for Control/Privacy and "*Equipment available on your work space*" for Comfort/Functionality. For each aspect of the physical working environment proposed, employees must indicate their satisfaction level on a 5-point scale ranging from 1 *"Not at all satisfactory"* to 5 *"Quite satisfactory"*. This scale is used to obtain three scores: a global satisfaction average, a "Control/Privacy" satisfaction average and a "Comfort/Functionalities" satisfaction average. These two satisfaction domains as well as the general factor each exhibit good internal consistency. Cronbach's alpha (α) measured for this scale and each of its dimensions is 0.84 for the general factor, 0.78 for the Control/Privacy dimension and 0.77 for the Comfort/Functionality dimension) (Fleury-Bahi & Marcouyeux, 2011). Other scales are available to measure job satisfaction, such as the French version of the Karasek Job Content Questionnaire (Brisson *et al.*, 1998), that of Veitch (Veitch et al., 2007), and the French version of the Minesota-Satisfaction-Questionnaire (Roussel, 1996). However, a fairly short

scale was preferable, in view of the number of subjects discussed in the questionnaire and a scale measuring exclusively satisfaction with the physical working space unrelated to the managerial aspect of the work.

The second section of the questionnaire, "Assessment of the noise environment of your work space", is used to assess the employees' noise environment. The general noise level perceived by the employees is measured first, then the perceived annoyance level. The noise environment is then detailed through 5 noise sources (operation of machines, ringing telephones, intelligible conversations, unintelligible conversations, people walking past), according to the perception frequency, the level of annoyance generated by each noise, the impact of these noises on work, and whether the noises are more annoying for some tasks. These five noise sources are described in the literature as the main sources of noise annoyance in open-space offices (Nemeck *et al.*, 1973; Sundström *et al.*, 1994). They are also the noise sources mentioned by the employees interviewed. The perception frequency is assessed using a 5-point scale ranging from 1 *"Never"* to 5 *"Permanently"*. The annoyance is also assessed using a 5-point scale ranging from 1 *"Not at all (annoying)"* to 5 *"Quite (annoying)"*. The employees are then invited to indicate by *"yes"* or *"no"* whether the noise proposed is more annoying depending on some of their work activities and, if *"yes"*, to list the various activities for which it seems more annoying.

The employees must then sort the sound sources from most annoying to least annoying. Two noise sources have been added to the five mentioned previously: noise generated by people (keyboard, opening and closing drawers) and noise related to one particular person. These two noise sources have been included with the previous ones since they were mentioned as annoying during the interviews.

A third section, "Your relation to noise in general", is dedicated to how people react to noise in general, i.e. their sensitivity level. There are 3 main noise sensitivity scales: the Weinstein Noise Sensitivity Scale (WNS) developed by Weinstein in 1978, the Fragebogen zur Erfassung der individuellen Lärmempfindlichkeit (LEF) developed by Zimmer and Ellermeier in 1999 and the Noise Sensitivity Questionnaire (NoiseQ) developed by Schütte in 2007. A shorter version has been created for each scale. We decided to use the reduced version of the Noise Sensitivity Questionnaire (NoiseQ) developed by Schütte *et al.* (2007a ; 2007b) since the constitution of the items on this scale is based on the WNS and LEF items which have been reformulated to obtain a better understanding of the content. The reduced version (NoiseQ-R) consists of 3 subscales (sleep, habitation, work) with 4 items each, making a total of 12 questions. The 12 questions are presented in the affirmative and the employees indicate

their level of agreement with the statement proposed, using a 4-point scale ranging from 1 *"Strongly disagree"* to 4 *"Strongly agree"*. The answers to all the questions are recoded from 0 to 3 and used to calculate a noise sensitivity score. A score of less than 1.11 indicates that the person is not sensitive to noise and a score of greater than 1.63 indicates that the person is sensitive to noise (Schütte *et al.*, 2007a). The short version was tested (Griefahn, 2008) and exhibits good internal consistency ($\alpha = 0.87$).

Lastly, the fourth section of the questionnaire, "You and your health", is used to assess how the respondents perceive their own health. This last section, consisting of 15 questions taken from the SATIN questionnaire developed by Grosjean, Kop, Formet-Robert and Althaus (2012), allows the employees to self-assess their own physical and moral health. The 15 questions are presented in the affirmative and the employees indicate their level of agreement with the statement proposed, using a 5-point scale. The questions are used to calculate a general perceived health score and four specific scores: perceived physical health, perceived psychological health, perceived symptoms and perceived stress. The scores range from 1 to 5. The scores are reversed for the last 10 questions. Scores close to 1 therefore indicate very poor health while scores close to 5 indicate a very satisfactory condition. More precisely, continuous scores greater than or equal to 3.5 indicate good health, continuous scores greater than or equal to 2.5 and strictly less than 3.5 indicate average health, and continuous scores strictly less than 2.5 indicate poor health (Grosjean, Kop, Formet-Robert & Althaus, 2012). The scale exhibits good internal consistency (α=0.91 for global health; α=0.93 for perceived physical health; α=0.83 for perceived stress; α=0.81 for perceived pains; α=0.80 for perceived psychic health).

3. Application case

3.1. Completing the questionnaire

The questionnaire was proposed to employees of seven French companies working in open-space offices. Acoustic measurements, of ambient noise in particular, were taken on three of these companies (designated A, B and C). The measurements were taken at different points in space, the number varying depending on the area of the room. At each point, the A-weighted equivalent noise level was calculated over a period of 30 seconds, the measurement being repeated 40 times (making a total measurement duration of 20 minutes). The values collected are shown on Figure 1. Each point represents a measurement position. Since the areas of the rooms vary considerably, 6 measurements points are used for company A, 14 for B and 20 for C. For each measurement point, the figure represents the mean value of the 40 values calculated together with the associated standard deviation. The mean values obtained are 56,

50 and 49 dBA for the three spaces. Note that the measurement variability is much higher in company C. Firstly, large differences are observed in the mean noise level between the measurement points, which is due to significant disparity in the layout (some work stations are much better insulated than others) and to different activities. In addition, for each measurement point, Figure 1 shows significant time variability. Work in this office is highly collaborative in fact, resulting in considerable movement of the employees and discussions at numerous different places during the day.

The respondents were requested to complete the questionnaire at work. They were asked to answer the questions spontaneously and anonymously. The answers are therefore subjective and specific to each person.

The answers collected were processed using statistical computation software (Statistica 10 – *Statsoft*).

3.2. Population

Out of all the employees interviewed in the various companies, we collected 237 questionnaires.

This figure is made up of 126 men and 111 women. The average age is 40 (SD = 11.8). The average seniority in the company is 19.3 years (SD = 12.9) and the average seniority in the current job is 3.5 years (SD = 3.3).

The scores obtained for assessment of global noise sensitivity show that, on average, the respondents are sensitive or even very sensitive to noise (mean = 2.2; SD = 0.5). The reliability analysis shows that the noise sensitivity scale exhibits good internal consistency. The Cronbach's alpha obtained is 0.84. It is consistent with the Cronbach's alpha of 0.87 obtained by Griefahn (1998).

The results of the perceived health indicate that, globally, the respondents consider themselves to be in good health (mean $\geq$ 3.5). However, the standard deviations are rather high, which would suggest that there is significant disparity between the answers, especially as regards the perceived stress. The reliability analysis shows that the perceived health scale exhibits good internal consistency. The Cronbach's alpha obtained for the scale measuring perceived general health is 0.89, 0.90 for perceived physical health, 0.83 for perceived psychic health, 0.77 for symptoms and 0.88 for stress. These results corroborate those of Grosjean *et al.* (2012).

3.3. Satisfaction regarding the work space

The scale of satisfaction regarding the work space (Fleury-Bahi & Marcouyeux, 2011) is used to obtain three scores: a global satisfaction average, a "Control/Privacy" satisfaction average

and a "Comfort/Functionality" satisfaction average. The results indicate that, overall, the employees interviewed consider that their physical working environment is moderately satisfactory (mean = 2.9; SD = 0.7). However, when the "Control/Privacy" and "Comfort/Functionality" dimensions are assessed independently, we see that the employees are globally less satisfied by the aspects related to the control and private space of their physical working environment (mean = 2.5; SD = 0.8) than by the factors related to the comfort and functionality of their office (mean = 3.3; SD = 0.7). There is a significant difference between the two scores [$z(236) = 11.87$; $p<.001$].

The reliability analysis shows that the job satisfaction scale exhibits good internal consistency. We obtain a Cronbach's alpha of 0.88 for the overall scale, 0.85 for the Control/Privacy dimension and 0.81 for the Comfort/Functionality dimension. We obtain virtually the same results as Fleury-Bahi and Marcouyeux (2011).

3.4. Assessment of the workplace noise environment

The noise present on the open work space is perceived by the employees of the various companies as being high and annoying. Most employees (56 %) consider that the noise level of their working environment is high (27 %) or very high (29 %) (see Figure 2) and 58 % consider that it is annoying (32 %) or very annoying (26 %) (see Figure 3). Only 2 % of the employees consider the noise present on the work space as being *"Not at all high"* and 4 % as *"Not at all annoying"*.

We calculated a Spearman's rank correlation between the global noise annoyance level and the global noise level felt on the work space (see Table 1). The result indicates that the noise level perceived and the annoyance felt are positively and strongly related ($r_s = 0.81$; $p<.01$).

When the employees are requested to assess the frequency at which the various noise sources present on their workplace are perceived (operation of machines, ringing telephones, intelligible conversations, unintelligible conversations, people walking past), we see that all the noise sources proposed are in fact present on the workplace and more or less important in terms of perception frequency (see Figure 4). The noise source heard most frequently comes from intelligible conversations, with 41 % of the employees interviewed declaring that they hear it *"Permanently"*, followed by ringing telephones, people walking past, operation of machines and unintelligible conversations. When they are requested to assess their annoyance level (see Figure 5), we observe that the noise source most present (intelligible conversations) is also the most annoying source. In contrast, the second most annoying noise source for employees, i.e. unintelligible conversations, is not the second noise source most often heard. Ringing telephones, operation of machines and people walking are assessed in practically the

same way. Concerning the noise of intelligible conversations, most employees (52 %) claim that the perceived annoyance is the same, whether they hear both people speaking or just one of them (telephone conversations).

For each noise aspect proposed (operation of machines, ringing telephones, intelligible conversations, unintelligible conversations and people walking past), we checked whether there was a link between the perception frequency and the perceived annoyance. The correlations presented in Table 1 indicate that, for all noise sources proposed, there is a positive and significant relation between the assessed perception frequency and the overall perceived annoyance level. We nevertheless observe a very low relation with the frequency at which operation of machines is perceived (r_s = 0.18; p<.01).

When the employees claimed that they were *"annoyed"* by a noise source (answers 2 to 5 on the scale proposed), we asked them to indicate by *"yes"* or *"no"* whether they considered this annoyance to be more important depending on the task they were performing and if *"yes, which"*. The results indicate that, for more than 50 % of the employees who answered that they were annoyed, the noise of machines (58%) and the noise of intelligible (67 %) and unintelligible (52 %) conversations seem to be even more annoying depending on the task being performed. *"Telephone conversations"* represent the main activity disturbed by noise, whatever the type. However, more than half of the respondents work in call centres. When we analyse these results according to the main activity of the employees (call centres or other), we observe in fact that the activity for which noise of intelligible conversations is more annoying is mainly *"telephone conversations"* for people working in call centres. For the others, however, the activities most often mentioned are *"reading"* and *"writing"*, before *"telephone conversations"*.

3.5. Noise annoyance and assessment of the physical working environment

The results presented in Table 1 also indicate that there is a significant relation between the level of noise annoyance perceived and the overall satisfaction regarding the work space (r_s = -0.54; p<.01). This relation is negative: as the satisfaction level increases, the noise annoyance level decreases. We observe that the aspects related to the comfort and functionality of the offices are significantly correlated (r_s = -0.32; p<.01) with the noise annoyance level, but less than the aspects related to control and privacy, which are both highly correlated (r_s = -0.64; p<.01). The more the employees have the feeling that they are unable to control their environment and/or have no privacy, the more they claim to be annoyed by ambient noise.

3.6. Noise annoyance and individual factors

We calculated a Spearman's rank correlation between the global noise annoyance level and the level of sensitivity to the noise declared (see Table 1). The result indicates that there is a positive and significant relation between annoyance and noise sensitivity (r_s = 0.34; p<.01).

We also measured the relation between the perceived noise annoyance and the declared health of the employees. We observe that there is no significant relation (p<0.01) between the global level of perceived noise annoyance and the physical health declared. In contrast, psychological health (r_s = -0.26; p<.01), symptoms (r_s = -0.24; p<.01), stress and overall health (r_s = -0.29; p<.01) are significantly correlated with the noise annoyance level. Considering the inversion of scores for the measurement of symptoms and stress (see Section 2. Drawing up the questionnaire), we observe that the greater the symptoms and the level of stress (score close to 1), the greater the noise annoyance.

3.7. Noise annoyance and sociodemographic factors

The following sociodemographic factors were recorded: sex, age, seniority in the company and seniority in the current job.

The Mann-Whitney variance test conducted between the *"sex"* and *"annoyance"* variables indicates that there is no difference between men and women as regards their assessment of annoyance.

We calculated a Spearman's rank correlation between the global noise annoyance level and the age of the respondents. We therefore categorised the *"age"* variable into five classes of ascending order. The result indicates that age and perceived annoyance are significantly related (r_s = 0.18; p<.01), although the correlation is very low.

As with the *"age"* variable, we categorised the *"seniority in the company"* and *"seniority in the job"* variables in ascending order so as to correlate them with the noise annoyance. Noise annoyance is significantly and positively correlated with seniority in the company (r_s = 0.22; p<.01) but not with seniority in the job.

4. Discussion and conclusion

The results of the application case demonstrate the relevance of our questionnaire to assess the physical working environment. The results corroborate the previous studies conducted in-situ and can also be used to check other factors which may have an impact on assessment of the physical working environment.

In line with the previous studies of Landström *et al.* (1995) and Job (1996), the results indicate that, although the noise levels do not exceed the legal action thresholds (Directive 2003/10/EC), most of the employees interviewed consider that the noise in their work space is high or very high (56 %) and that it is annoying or very annoying (58 %). Consequently, the

true noise intensity only partly accounts for the perceived noise intensity and the perceived annoyance.

The questionnaire is used to collect information on factors other than the acoustic environment in order to assess their influence on perception of the workplace noise environment or whether they are themselves affected by the presence of noise. The results of the practical case therefore demonstrate that the more the employees feel that they are unable to control their environment and have no privacy, the more they claim to be annoyed by ambient noise. These results confirm those of Lee and Brand (2005).

Noise nuisances are clearly present in open-space offices. The annoyance felt by the employees and the consequences on their work and health must therefore be assessed. Lastly, note that the noise level measured is not representative of the annoyance expressed by the employees. Figure 6 compares objective noise level values and subjective annoyance values for the 3 offices in which these two measurements were taken. We subtracted 48 from the mean levels measured in each office for data comparison purposes. The subjective assessments represented are the answers to the questions "Generally, would you say that the noise level in your working environment is high" and "Generally, would you say that the noise level in your working environment is annoying". The maximum noise level is observed in office A, although the annoyance expressed by the occupants is much less than that expressed by the occupants of offices B and C. The opposite effect is observed in office C. Note that all the differences observed on Figure 5 are significant at the 0.05 level (Student's t-test), except as regards the mean noise level in offices B and C, which cannot be considered as different.

Factors other than the physical level must therefore be taken into account to describe the annoyance perceived by the employees.

In conclusion, the questionnaire would appear to be a complementary and necessary tool for physical measurements when assessing the noise environment of open-space offices. In particular, it may be used to best define the improvements required in an office and to measure the efficiency of these improvements.

436
437 References

438 Baddeley, A. D. (2000). The phonological loop and the irrelevant speech effect: some
439 comments on Neath. *Psychonomic Bulletin and Review, 7,* 544-549.

440 Banbury, S. and Berry, D. C. (1998). Disruption of office-related tasks by speech and office
441 noise. British Journal of Psychology, *89*, 499-517.

442 Banbury, S. P., & Berry, D. C. (2005). Office noise and employee concentration: Identifying
443 causes of disruption and potential improvements. *Ergonomics*, *48*, 25-37.

444 Beaman, P. (2005). Auditory distraction from low-intensity noise: A review of the
445 consequences for learning and workplace environments. *Applied Cognitive*
446 *Psychology*, *19*, 1041-1064.

447 Bodin Danielsson, C., & Bodin, L. (2008). Office-type in relation to health, well-being and
448 job satisfaction among employees. *Environment and Behavior*, *40*(5), 609-636.

449 Bodin Danielsson, C., Singh Chungkham, H., Wulff, C. and Westerlund, H. (2014). Office
450 design's impact on sick leave rates. *Ergonomics*, *57*(2), 139-147.

451 Brisson, C., Blanchette, C., Gimont, C., Dion, G., Moisan, J., Vézina, M., Dagenais, G. R. and
452 Mâsse, L. (1998). Reliability and validity of the French version of the 18-item Karasek
453 Job Content Questionnaire. *Work and stress, 12*(4), 322-336.

454 Buchner, A., Steffens, M. C., Irmen, L. and Wender, K. F. (1998). Irrelevant auditory material
455 affects counting. *Journal of Experimental Psychology: Learning, Memory and*
456 *Cognition*, *24*, 48-67.

457 De Croon, E. M., Sluiter, J. K., Kuijer, P. P. F. M., and Frings-Dresen, M. H. W. (2005). The
458 effect of office concepts on worker health and performance: a systematic review of the
459 literature. *Ergonomics, 48,* 119-134.

460 Des Isnards, A. et Zuber, T. 2008, *L'open space m'a tuer*. Hachette Littératures, France.

461 Directive 2003/10/EC of the European Parliament and of the Council of 6 February 2003 on
462 the minimum health and safety requirements regarding the exposure of workers to the
463 risks arising from physical agents (noise).

464 Fischer, G.N., 1989. *Psychologie des espaces de travail*. Colin, Paris.

465 Fleury-Bahi, G., and Marcouyeux, A. (2011). "Evaluer la satisfaction envers l'espace de
466 travail: Développement d'une échelle et première validation," *ePTO, 27*.

467 Griefahn, B. (2008). "Determination of noise sensitivity within an internet survey using a
468 reduced version of the Noise Sensitivity Questionnaire". *Journal of the Acoustical*
469 *Society of America, 123*(5), 3449-3449.

Grosjean, V., Kop, J., Formet-Robert, N., and Parmentier, C. (2012). "Un questionnaire d'évaluation de la santé au travail pour la prévention, le diagnostic et l'intervention – Manuel d'utilisation". *Les Notes Scientifiques et Techniques de l'INRS, 272*, 39 p.

Haka, M., Haapakangas, A., Keränen, J., Hakala, J., Keskinen, E., & Hongisto, V. (2009). Performance effects and subjective disturbance of speech in acoustically different office types – a laboratory experiment. *Indoor Air, 19*, 454-467.

Haapakangas, A., Helenius, R., Keskinen, E. and Hongisto, V. (2008). Perceived acoustic environment, work performance and well-being – survey results from Finish offices. *Proceeding of The 9th Congress of the International Commission on the Biological Effects of Noise, (ICBEN) 2008, July 21-25, Mashantucket, Connecticut, USA 434-441*.

Hongisto, V. (2005). A model predicting the effect of speech of varying intelligibility on work performance. *Indoor Air*, *15*, 458-468.

Huang, Y., Robertson, M. M. and Chang, K. (2004). The role of environmental control on environmental satisfaction, communication, and psychological stress: effects of office ergonomic training. *Environment and Behavior, 36(5)*, 617-637.

ISO/DIS 3382-3. Acoustics – measurement of room acoustic parameters – part 3: open-plan spaces. *International Organization for Standardization*, 2012.

Job, R. F. S. (1988). Community response to noise: a review of factors influencing the relationship between noise exposure and reaction. *Journal of Acoustical Society of America*, *83*, 991-1001.

Job, R. F. S. (1996). The influence of subjective reactions to noise and health effects of the noise. *Environment International*, *22*(1), 93-104.

Jones, D. M., Miles, C. and Page, J. (1990). Disruption of proofreading by irrelevant speech: effects of attention, arousal or memory? *Applied Cognitive Psychology*, *4*, 89-108.

Jones, D. M. & Macken, W. J. (1995). Auditory babble and cognitive efficiency: Role of number of voices and their location. *Journal of Experimental Psychology Applied*, *1*(3), 216-226.

Kaarlela-Tuomaala, A., Helenius, R., Keskinen, E. and Hongisto, V. (2009). Effects of acoustic environment on work in private office rooms and open-plan offices – longitudinal study during relocation. *Ergonomics, 52*(11), 1423-1444.

Kjellberg, A., Landström, U., Tesarz, M., Soederberg, L., and Akerlund, E. (1996). The effects of nonphysical noise characteristics, ongoing task and noise sensitivity on

503 annoyance and distraction due to noise at work. *Journal of Environmental Psychology, 16*(2), 123-136.
505 Kjellberg, A. and Sköldström, B. (1991). Noise annoyance during the performance of
506 different non-auditory tasks. *Perceptual and Motor Skills, 73*, 39-49.
507 Knez, I. and Hygge, S. (2002). Irrelevant speech and indoor lighting: effects on cognitive
508 performance and self-reported affect. *Applied Cognitive Psychology, 16*, 709-718.
509 Landström, U., Akerlund, E., Kjellberg, A., Tesarz, M. (1995). Exposure levels, tonal
510 components and noise annoyance in working environments. *Environment*
511 *International, 21*, 265-275.
512 LeCompte, D. C. (1994). Extending the irrelevant speech effect beyond serial recall. *Journal*
513 *of experimental Psychology: Learning, Memory and Cognition*, *20*, 1396-1408.
514 Lee, S. Y. and Brand, J. L. (2005). Effects of control over office workspace on perceptions of
515 the work environment and work outcomes. *Journal of Environmental Psychology, 25*,
516 323-333.
517 Lee, S. Y. and Brand, J. L. (2010). Can personal control over the physical environment ease
518 distractions in office workplaces? *Ergonomics, 53*(3), 324-335.
519 Marmot, A. F., Eley, J., Stafford, M., Stansfeld, S. A., Warwick, E. and Marmot, M. G.
520 (2006). Building health: an epidemiological study of "sick building syndrome" in the
521 Whitehall II study. *Occupational and Environmental Medicine, 63*, 283-289
522 Miedema, H. M, Vos, H. (1998). Exposure-response relationships for transportation noise.
523 *Journal of Acoustical Society of America, 104*(6), 3432–3445.
524 Moch, A., and Maramotti, I. (1995). Les ambiances de la ville : du stress au confort. *Pratiques*
525 *Psychologiques, 2*, 17-25.
526 Nemecek, J., & Grandjean, E. (1973). Noise in landscaped offices. *Applied Ergonomics*, *4*,
527 19-22.
528 Oswald, C. J. P., Tremblay, S. and Jones, D. M. (2000). Disruption of comprehension by the
529 meaning of irrelevant sound. *Memory, 8*, 345-350.
530 Pejtersen, J., Allermann, L., Kristensen, T. S. and Poulsen, O. M. (2006). Indoor climate,
531 psychosocial work environment and symptoms in open-plan offices, *Indoor Air, 16*,
532 392-401.
533 Roussel, P. (1996). *Rémunération, motivation et satisfaction au travail*. Paris: Editions
534 Economica, collection Recherche en Gestion.
535 Sailer, U. and Hassenzahl, M. (2000). Assessing noise nuisance: an improvement-oriented
536 approach. *Ergonomics*, *43*, 1920-1938.

SBiB (2010). *Enquête Suisse dans les bureaux,* 159 p.

Schutte, M., Marks, A., Wenning, E., and Griefahn, B. (2007a). "The development of the noise sensitivity questionnaire". *Noise and Health, 9*(34), 15-24.

Schutte, M., Sandrock, S., and Griefahn, B. (2007b). "Factorial validity of the noise sensitivity questionnaire". *Noise and Health, 9*(37), 96-100.

Sundstrom, E. and Sundstrom, M. G. (1986). *Work places: The psychology of the physical environment in offices and factories.* New York, USA: Cambridge University Press.

Sundstrom, E., Town, J. P., Rice, R. W., Osborn, D. P., Brill, M. (1994). Office noise, satisfaction, and performance. *Environment and Behavior, 26*, 195-222.

Veitch, J. A., Charles, K. E., Farley, K. M. J. and Newsham, G. R. (2007). A model of satisfaction with open-plan office conditions: COPE field findings. *Journal of Environmental Psychology, 27*(3), 177-189.

Weinstem, N. D. (1978). Individual differences in reaction to noise: a longitudinal study in a college dormitory. *Journal of Applied Psychology, 63*, 458-466.

Zimmer, K. and Ellermeier, W. (1999). Psychometric properties of four measures of noise sensitivity: A comparison, *Journal of Environmental Psychology*, 19, 295-302.