



HAL
open science

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

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

► To cite this version:

Marjorie Pierrette, Etienne Parizet, P. Chevret, J. Chatillon. Noise effect on comfort in open-space offices: development of an assessment questionnaire. *Ergonomics*, 2015, 58 (1), pp.96-106. 10.1080/00140139.2014.961972 . hal-01714040

HAL Id: hal-01714040

<https://hal.science/hal-01714040>

Submitted on 21 Feb 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

10
11

Abstract

12 It is currently accepted that noise is one of the most important annoyance factors in open-
13 space offices. However, noise levels measured on open spaces of the tertiary sector rarely
14 exceed 65 dB(A). It therefore appears necessary to develop a tool that can be used to assess
15 the noise environment of these offices and identify the parameters to be taken into
16 consideration when assessing the noise annoyance. This paper presents a questionnaire to be
17 filled by people working in such environment, and a case study in different open plan offices.
18 The majority of the 237 respondents consider that the ambient noise level in their
19 environment is high and that intelligible conversations between their colleagues represent the
20 main source of noise annoyance. This annoyance was significantly correlated with their
21 evaluation of sound intensity, which could not be represented by A-weighted level
22 measurements.
23

24

25 **Practitioner summary**

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

30

31
32

1. Introduction

33 The modern open-space concept was developed by two German consultants, the brothers
34 Eberhard and Wolfgang Schnelle, in the 1950s. This type of partitionless office layout found
35 considerable success in the United States and has become much more widespread in Europe
36 since 1980. Most companies have now adopted this type of work space (according to a survey
37 conducted in 2008, 60 % French companies use open-space offices), in all business sectors.
38 There is no specific definition or size of the open-space office and the layout of these work
39 spaces depends on the individual companies (Bodin Danielsson & Bodin, 2008). They may be
40 simple collective offices or completely open platforms accommodating several dozen
41 employees. The intention of these open-space offices is to improve communication between
42 colleagues and therefore facilitate team or project work, save space and be closer to the
43 managers. Employees nevertheless often complain that they permanently feel spied upon (e.g.
44 "*L'open space m'a tuer*" (Open-space killed me) by Alexandre des Isnards & Thomas Zuber,
45 2008) and that they suffer from a high level of ambient noise (noise annoyance related to the
46 work of the other employees and the equipment).

47 According to one highly exhaustive survey conducted in 2010 by the Haute Ecole de Lucerne
48 on behalf of the Swiss State Secretariat for the Economy (SBiB, 2010), noise is one of the
49 main annoyance factors in open spaces. This survey agrees with several studies which
50 demonstrated that the acoustic environment was considerably less satisfactory in open-space
51 offices than in private offices (e.g. Nemecek & Grandjean, 1973; Sundstrom *et al.*, 1994; de
52 Croon *et al.*, 2005; Kaarlela-Tuomala *et al.*, 2009). For example, Kaarlela-Tuomala *et al.*
53 (2009) studied employees who moved from a private office to an open space. The study
54 highlights the negative effects of open space on 31 employees interviewed before and after
55 the move. The sound level increased significantly and resulted in more disruptions during
56 work, the feeling of privacy decreased, concentration difficulties increased. This study also
57 demonstrates a lack of the beneficial effects generally associated with open-space offices:
58 cooperation becomes less pleasant and the circulation of information is unchanged. The
59 researchers conclude that work in open space is not recommended.

60 Numerous laboratory experiments have demonstrated that noise in offices has a disrupting
61 effect on cognitive performance, such as mental arithmetic (e.g. Banbury & Berry, 1998),
62 learning of associated words or a text (e.g. LeCompte, 1994; Banbury & Berry, 1998),
63 counting points displayed visually (e.g. Buchner *et al.*, 1998), correction tasks (e.g. Jones *et al.*,
64 1990), understanding text and recall (e.g. Knez & Hygge, 2002; Oswald *et al.*, 2000).

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

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

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

93 *Noise source*

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

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

122 *Task*

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

131 *Noise sensitivity*

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

141 *Working environment*

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

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

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

173 **2. Drawing up the questionnaire**

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

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

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

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

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

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

234 their level of agreement with the statement proposed, using a 4-point scale ranging from 1
235 "*Strongly disagree*" to 4 "*Strongly agree*". The answers to all the questions are recoded from
236 0 to 3 and used to calculate a noise sensitivity score. A score of less than 1.11 indicates that
237 the person is not sensitive to noise and a score of greater than 1.63 indicates that the person is
238 sensitive to noise (Schütte *et al.*, 2007a). The short version was tested (Griefahn, 2008) and
239 exhibits good internal consistency ($\alpha = 0.87$).

240 Lastly, the fourth section of the questionnaire, "You and your health", is used to assess how
241 the respondents perceive their own health. This last section, consisting of 15 questions taken
242 from the SATIN questionnaire developed by Grosjean, Kop, Formet-Robert and Althaus
243 (2012), allows the employees to self-assess their own physical and moral health. The 15
244 questions are presented in the affirmative and the employees indicate their level of agreement
245 with the statement proposed, using a 5-point scale. The questions are used to calculate a
246 general perceived health score and four specific scores: perceived physical health, perceived
247 psychological health, perceived symptoms and perceived stress. The scores range from 1 to 5.
248 The scores are reversed for the last 10 questions. Scores close to 1 therefore indicate very
249 poor health while scores close to 5 indicate a very satisfactory condition. More precisely,
250 continuous scores greater than or equal to 3.5 indicate good health, continuous scores greater
251 than or equal to 2.5 and strictly less than 3.5 indicate average health, and continuous scores
252 strictly less than 2.5 indicate poor health (Grosjean, Kop, Formet-Robert & Althaus, 2012).
253 The scale exhibits good internal consistency ($\alpha=0.91$ for global health; $\alpha=0.93$ for perceived
254 physical health; $\alpha=0.83$ for perceived stress; $\alpha=0.81$ for perceived pains; $\alpha=0.80$ for perceived
255 psychic health).

256 **3. Application case**

257 3.1. Completing the questionnaire

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

268 50 and 49 dBA for the three spaces. Note that the measurement variability is much higher in
269 company C. Firstly, large differences are observed in the mean noise level between the
270 measurement points, which is due to significant disparity in the layout (some work stations
271 are much better insulated than others) and to different activities. In addition, for each
272 measurement point, Figure 1 shows significant time variability. Work in this office is highly
273 collaborative in fact, resulting in considerable movement of the employees and discussions at
274 numerous different places during the day.

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

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

280 3.2. Population

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

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

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

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

299 3.3. Satisfaction regarding the work space

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

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

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

314 3.4. Assessment of the workplace noise environment

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

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

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

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

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

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

359 3.5. Noise annoyance and assessment of the physical working environment

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

369 3.6. Noise annoyance and individual factors

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

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

381 3.7. Noise annoyance and sociodemographic factors

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

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

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

391 As with the "*age*" variable, we categorised the "*seniority in the company*" and "*seniority in*
392 *the job*" variables in ascending order so as to correlate them with the noise annoyance. Noise
393 annoyance is significantly and positively correlated with seniority in the company ($r_s = 0.22$;
394 $p < .01$) but not with seniority in the job.

395 4. Discussion and conclusion

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

400 In line with the previous studies of Landström *et al.* (1995) and Job (1996), the results
401 indicate that, although the noise levels do not exceed the legal action thresholds (Directive
402 2003/10/EC), most of the employees interviewed consider that the noise in their work space is
403 high or very high (56 %) and that it is annoying or very annoying (58 %). Consequently, the

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

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

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

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

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

432

433

434

435

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.

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

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

476 Haapakangas, A., Helenius, R., Keskinen, E. and Hongisto, V. (2008). Perceived acoustic
477 environment, work performance and well-being – survey results from Finish offices.
478 *Proceeding of The 9th Congress of the International Commission on the Biological*
479 *Effects of Noise, (ICBEN) 2008, July 21-25, Mashantucket, Connecticut, USA 434-*
480 *441.*

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

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

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

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

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

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

495 Jones, D. M. & Macken, W. J. (1995). Auditory babble and cognitive efficiency: Role of
496 number of voices and their location. *Journal of Experimental Psychology Applied*,
497 1(3), 216-226.

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

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

503 annoyance and distraction due to noise at work. *Journal of Environmental Psychology*,
504 *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.

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

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

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

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

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

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

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

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

553

554

555