ARCHIVES OF ACOUSTICS
33, 3, 331–340 (2008)

ANALYSIS OF ANNOYANCE CAUSED BY INFRASOUND AND LOW-FREQUENCY NOISE DURING MENTAL WORK

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(*received March 19, 2008; accepted June 16, 2008*)

This paper presents the results of low-frequency noise (LFN) annoyance tests in laboratory conditions on a model workstation conceptual mental work. Group of volunteers: 60 persons (30 women and 30 men) participated in the experiment consisting in completing psychological tests in three different acoustic conditions. The tests results have shown significant differences in subjective assessment of noise annoyance depending on the gender and reactivity level of surveyed persons.

Keywords: infrasound, low-frequency noise, annoyance, working environment.

1. Introduction

The permissible values for infrasonic noise in working environment in Poland (equivalent-continuous G-weighted sound pressure level normalized to a nominal 8-hour workday $L_{\mathrm{Geq,8h}}$ 102 dB and unweighted peak sound pressure level, L_{LINpeak} 145 dB) [1] are established due to the harmful effect of this noise on health and are more appropriate for industrial conditions. Low-frequency noise (LFN) (including infrasound) is one of the most harmful and annoying factors that occurs in human working and living environments [2, 3]. There are no actual criteria for infrasound and LFN annoyance in the working environment, especially when performing mental conceptual work and tasks that require concentration and attention.

Surveys concerning noise conducted in working environment in approximately 110 rooms in office buildings have shown many complaints of the employees about annoying, irritating and tiring low-frequency noise or infrasound, which makes it difficult to work or causes excessive sleepiness and fatigue, despite the fact that the permissible values for infrasonic noise were not exceeded [4].

The low-frequency components from the 20–125 Hz frequency range are often the cause of employee complaints concerning noise annoyance at the working environment.

This paper presents results of tests of annoyance caused by infrasound and LFN during mental work conducted in laboratory conditions. The results of described tests will be helpful for developing LFN annoyance criteria for workstations where conceptual works that require concentration and attention takes place.

2. Experiment description

2.1. Methodology

A group of 60 persons (30 women and 30 men), aged 19–25, has been selected from about 200 volunteers. The selected persons had normal hearing and different properties of the nervous system, from the point of view of the reactivity level. From the selected group 30 persons (including 15 women and 15 men) were defined as low-reactive (LR)[(1)] and 30 persons (including 15 women and 15 men) were defined as high-reactive (HR)[(2)].

The subjects (60 persons) took part in an experiment that consisted in completing psychological tests from the Vienna Test System: ALS – work performance test [5] and DAUF – continuous attention test [6], in three different acoustic conditions. The surveyed persons were located in a separated test room (sound-proof booth) and the noise sources were located outside. The layout of laboratory is shown in Fig. 1.

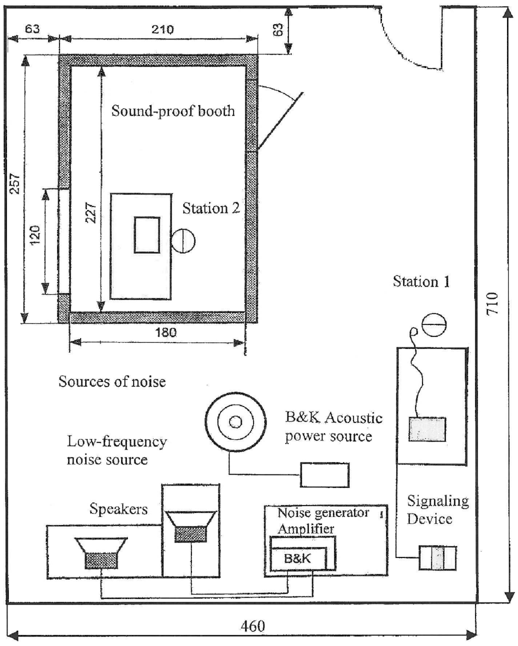

Fig. 1. Laboratory layout.

(1) LR – high resistance to high level of stimulation.

(2) HR – low resistance to high level of stimulation.

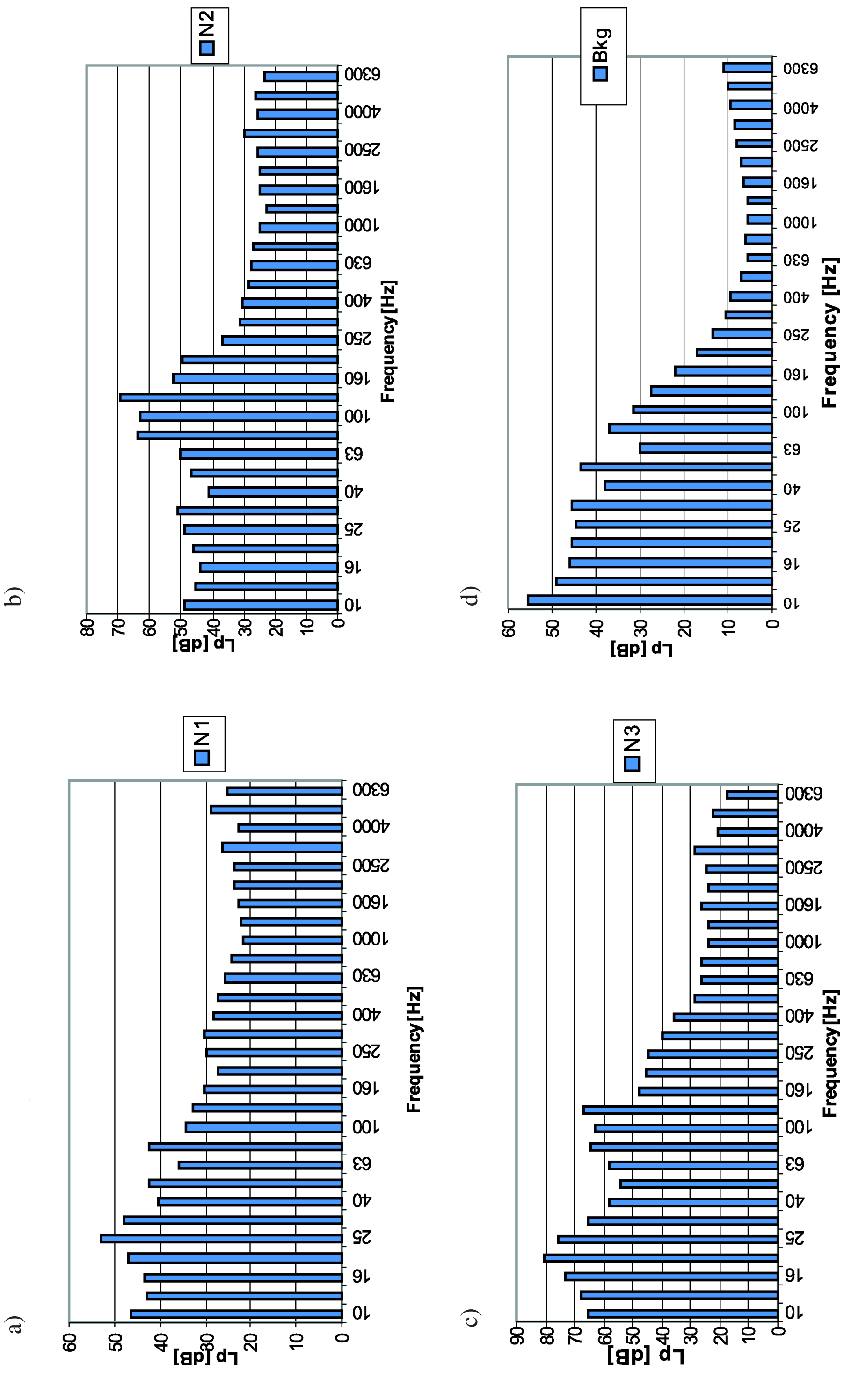

Fig. 2. Noise spectrum inside the test room (sound-proof booth) for different experiment types: a) Noise N1 – reference noise, b) Noise N2 – low-frequency noise, c) Noise N3 – noise with infrasound components, d) Bkg. – background noise inside the test room.

Duration time of a single session was approximately 60 minutes. Everyone participated in 3 sessions and one trial session, which took place not more often than once/twice per week, always at the same time. The test signal used during the experiment, which was recoded in the test room is shown in Fig. 2 and Table 1.

Table 1. List of acoustic parameters during laboratory tests.

No	Name of acoustic conditions	Acoustic parameters in the test room		
		$L_{\text{Aeq},T}$ [dB]	L_{Cpeak} [dB]	$L_{\text{Geq},T}$ [dB]
1.	Noise N1 – reference noise (computer noise)	35.0	64.6	62.0
2.	Noise N2 – low-frequency noise (LFN)	53.2	82.8	62.1
3.	Noise N3 – noise with infrasound components	52.9	88.4	90.3
4.	Bkg. – background noise inside the separated test room	22.0	63.5	61.8

$L_{\text{Geq},T}$ – equivalent G-weighted sound pressure level over duration T,
$L_{\text{Aeq},T}$ – equivalent-continuous A-weighted sound pressure level over duration T,
L_{Cpeak} – C-weighted peak sound pressure level.

After the test session, persons completed questionnaires aimed at: subjective rating of annoyance and symptoms experienced during the tests conditions.

The experiment used the graphical 100-point noise annoyance scale (NAS) (not annoying – very annoying) [7, 8] as subjective assessments of annoyance caused by noise and the survey of sensations and complaints (Table 2) [7] related to the exposure to noise as a subjective method of evaluation of symptoms relates to the influence of infrasound and LFN during the experiment.

Table 2. Survey of reported sensations and complaints.

Sensations during test session		**Complaints** during test session	
1-S – No sensations	☐	1-C – No complaints	☐
2-S – I heard noise	☐	2-C – Headache	☐
3-S – I felt pressure in ears	☐	3-C – Concentration problems	☐
4-S – I felt pressure in head	☐	4-C – Dizziness	☐
5-S – I felt vibrations in parts of body	☐	5-C – Sleepiness	☐
6-S – I felt discomfort	☐	6-C – Fatigue	☐
7-S – Other	☐	7-C – Other	☐

2.2. Statistical analysis

The statistical analysis concerned the comparison of results (the subjective and objective assessment) obtained during individual experiments with different types of noise.

The following statistical methods were used in the analysis:

– ANOVA test (variation analysis) – parametrical test for comparing mean values of analyzed test indexes,

– Kruskal–Wallis One Way Analysis by Ranks test – non-parametrical test for comparing distribution of analyzed test index,
– Kolmogorov–Smirnov test – test for verifying the hypothesis about measurement results distribution normality,
– Brown–Forsyth test for verifying the variation homogeneity.

All statistical tests were done with an assumed significance level of $p < 0.05$.
The statistical analysis employed software Statistica 6.0 (StatSoft).

3. Results of tests

The preliminary analysis of results shows that different noise levels used in individual types of experiments did not influence the objective measurements of psychophysical fitness of surveyed persons.

Significant result differentiation can be found in the subjective assessment of noise annoyance. Detailed results of variance analysis show statistically significant differences in the perception of noise by persons with different gender and reactivity level.

The first case concerns the difference between average values of annoyance rating on the 100-point NAS collected after the experiment in the group of women and men in total (Fig. 3). The difference in perception of noise N3 between women and men was 10.73 points and it is statistically significant ($p = 0.014$). This result allows to state that men and women perceive the noise N3 annoyance differently. This noise (noise with infrasound components) is more annoying to women. The difference in perception of noise N2 between women and men was 8.9 points and isn't statistically significant ($p = 0.054$).

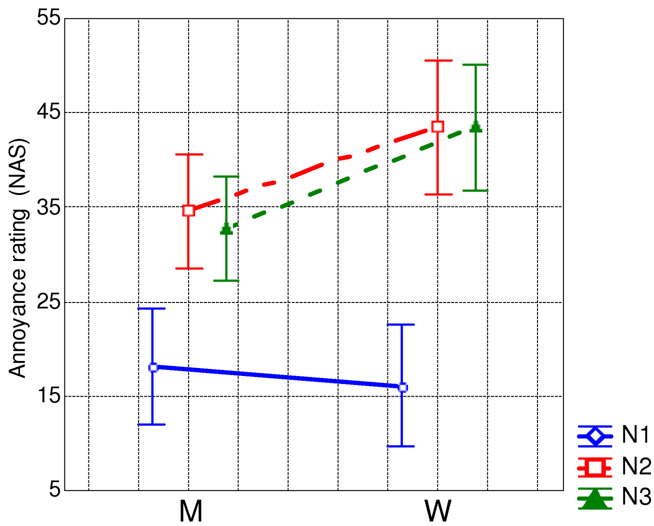

Fig. 3. Average values of annoyance rating on the 100-point NAS in different experiment types (noise: N1, N2, N3) with differentiation of gender of surveyed persons: M – men, W – women. With marked 95% confidence interval.

The second case is related to the differences between average values on NAS collected after conducting the experiment with noise in the HR and LR group of persons.

Figure 4 shows the average values on NAS in different experiment types with differentiation of the reactivity of surveyed persons.

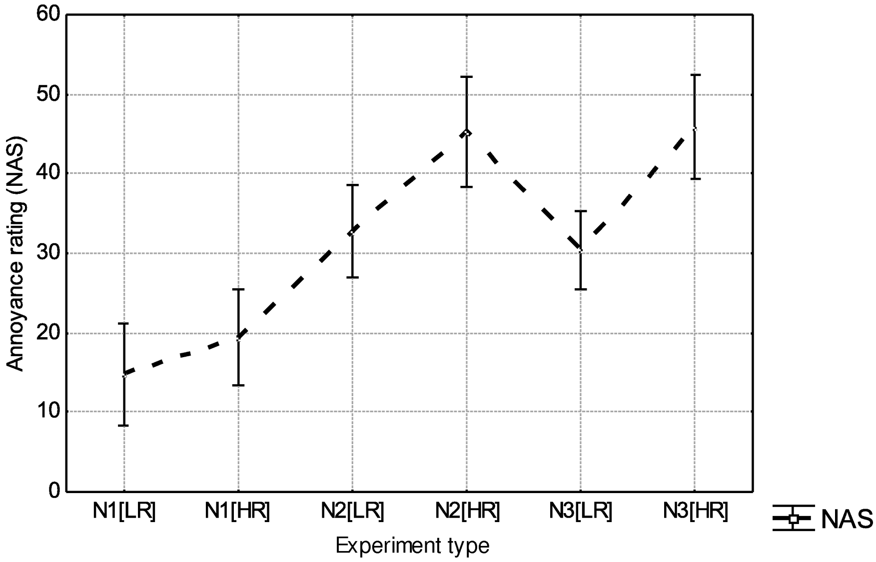

Fig. 4. Average values of annoyance rating on the100-point NAS in different experiment types (noise: N1, N2, N3) with differentiation of the reactivity of surveyed persons (LR, HR). With marked 95% confidence interval.

The calculations have shown the existence of statistically significant difference in the perception of noise by LR group and the HR group depending on noise type.

In the LR group there was a noticeable difference in the perception of various types: the difference between noise N2 and noise N1 is 18.00 points ($p < 0.001$), and the difference between noise N3 and N1 is 15.63 points ($p < 0.001$). However, no statistically important difference has been stated for the mean values on NAS in N2 (low-frequency noise) and N3 (noise with infrasound components) types ($p = 0.661$), this means that for the surveyed persons the change of infrasound level during the experiment was undistinguishable from the noise annoyance viewpoint.

Detailed calculations for the HR group indicated a similar dependence as for the LR group. The surveyed HR persons felt a difference in noise annoyance level between noise N2 and noise N1, the difference is 24.86 points ($p < 0.001$), and the difference between noise N3 and noise N1, the difference was 26.40 points ($p < 0.001$).

At the same time the analysis has shown no noise annoyance differences between the types: noise N2 and noise N3 ($p = 0.959$), this that for the surveyed persons the change of infrasound level during the experiment (L_{Geq} 62 dB $-$ L_{Geq} 90 dB) was undistinguishable from the viewpoint of noise annoyance.

Furthermore, the analysis has shown the existence of differences in perceiving noise annoyance for the N2 type of the experiment, between the LR and HR persons, this difference is 12.56 points and it is statistically significant ($p = 0.0073$), also for the N3 type of the experiment the difference is 15.47 points and it is statistically significant ($p < 0.001$), which means that the surveyed persons from the HR group assessed the annoyance of N2 and N3 noise higher that the persons from the LR group.

The statistical analysis has shown the existence of statistically significant differences in the number of sensations and complaints reported by the test participants, after the completion of each type of test.

The average number of sensations (such as pressure in ears, discomfort, pressure in the head, hearing noises) reported by HR and LR persons increases in the N2 and N3 types of the experiment in comparison to the experiment type N1 – reference noise (Fig. 5a).

The average number of complaints (such as headache, problems with concentration and attention, sleepiness or fatigue) increases only for the HR persons working in N2 (low-frequency noise) or N3 (noise with infrasound components) environment in comparison to the experiment type N1 – reference noise (Fig. 5b). A greater number of complaints in noise N2 and noise N3 were reported by persons with high reactivity level, in comparison to the low-reactivity group.

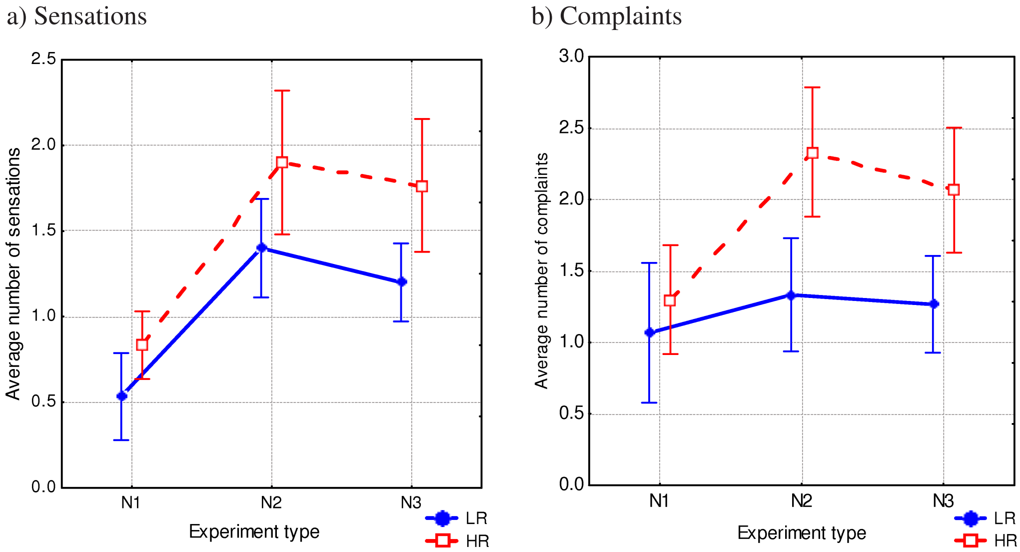

Fig. 5. Average number of: a) sensations, b) complaints reported by persons with different reactivity (LR, HR) according to experiment types (noise: N1, N2, N3). With marked 95% confidence interval.

Majority of the surveyed persons (from the HR group) complained about sleepiness (83%) when working in noise N2 and noise N3 (Fig. 6a) and fatigue when working in noise N2 (63%) and noise N3 (46%) (Fig. 6b).

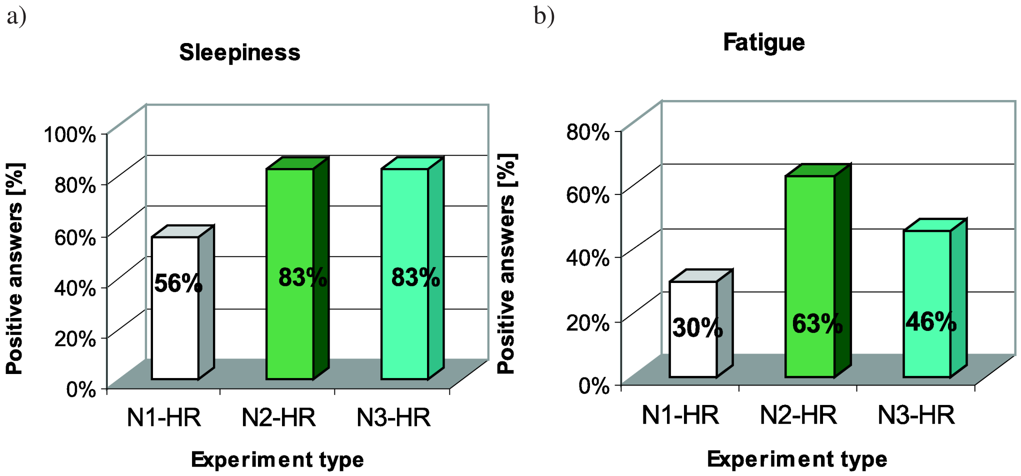

Fig. 6. Survey results – assessment of reported complaints of persons with high reactivity (HR) according to experiment types (noise: N1, N2, N3): a) Sleepiness, b) Fatigue.

Approximately 53% of surveyed persons from the HR group had problems with concentration caused by noise N2, and approximately 43% in case of noise N3 (Fig. 7).

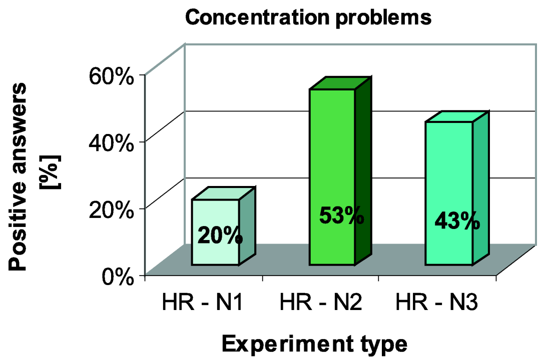

Fig. 7. Survey results – assessment of reported complaints (concentration problems) of persons with high reactivity (HR) according to experiment types (noise: N1, N2, N3).

4. Conclusions

The study conducted in laboratory conditions has shown significant differentiation of results in the field of subjective assessment of noise annoyance.

The obtained results can be interpreted as a proof of existence of noticeable low-frequency noise (noise N2) and noise with infrasound components (noise N3) annoyance during mental work (higher rating on the 100-point NAS, greater number of reported sensations and complaints) in comparison to reference noise (noise N1).

The results have shown that noise with infrasound components (noise N3) is perceived as more annoying (higher rating on the 100-point NAS) by women than by men.

The detailed analysis have shown that low-frequency noise (noise N2) and noise with infrasound components (noise N3) is perceived as more annoying during mental work (higher score in the 100-point scale NAS, greater number of reported complaints) by persons with high reactivity level, in comparison to the low-reactivity group.

However, we did not observe any significant diversification in the assessment of noise with higher infrasound components in its spectrum (noise N3: $L_{\mathrm{Geq}} = 90$ dB) and noise with lower infrasound components in its spectrum (noise N2 $L_{\mathrm{Geq}} = 62$ dB) with groups of persons with the same reactivity level.

Majority of the surveyed persons from the HR group complained about sleepiness (83% of HR persons) when working in LFN (noise N2) and noise with infrasound components (noise N3) and fatigue (63% of HR persons) when working in LFN (noise N2). Approximately 53% of surveyed persons with high reactivity level had problems with concentration in case of low-frequency noise (noise N2).

The problem of LFN annoyance when carrying out precision and conceptual work requires further research.

Acknowledgments

We are grateful to Andrzej Sobolewski, M.Sc. (Eng), and Marcin Abramowicz for their help in this experiment.

This work was supported in part by Poland's Ministry of Science and Higher Education (grant 2 P05D 018 28/2005-2008).

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