inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.0

LOW FREQUENCY NOISE "POLLUTION" INTERFERES WITH PERFORMANCE

J. Bengtsson*, K. Persson Waye*, A. Kjellberg, S. Benton*****

* Department of Environmental Medicin, University of Gothenburg, Box 414, 405 30, Gothenburg, Sweden

** Institute for Working Life, Institute for Working Life, 171 84, Solna, Sweden

*** Department of Psychology, University of Westminster, 309 Regent Street, W1R 8AL, London, United Kingdom

Tel.: +46 (0)31 773 36 21 / Fax: +46 (0)31 82 50 04 / Email: johanna.bengtsson@envmed.gu.se

Keywords:
LOW FREQUENCY NOISE, NOISE SENSITIVITY, PERFORMANCE, SUBJECTIVE ESTIMATION

ABSTRACT
In the study, 32 subjects performed four performance tests when exposed to a mid-frequency noise or a low frequency noise, both at a level of 40 dBA. The results indicate that low frequency noise interfered with a proof reading test by decreasing the number of markings made per line read. The results furthered showed that the response time in a verbal grammatical reasoning test was longer over time in the low frequency noise exposure. Subjects categorized as sensitive to low frequency noise generally performed less well and also reported the highest annoyance due to low frequency noise.

1 - INTRODUCTION
Modern technology and computerised machinery has decreased the high noise exposure but introduced other types of occupational noises. Many working environments contain noises dominated by the frequency 20 to 200 Hz (LFN). The noise is emitted from ventilation/air condition systems but also caused by the lower attenuation by the walls, floor and ceiling. Symptoms reported in connection with annoyance due to LFN and which could reduce a person's working capacity are fatigue, headache and irritation [1, 2]. Previous studies of effects due to LFN [3] show that persons sensitive to LFN were not necessarily sensitive to noise in general as measured by general noise sensitivity scales. It is therefore important to classify subjects more specifically sensitive to LFN. The aim was to evaluate the influence of LFN on performance by answering the questions: Can LFN at a level normally present in control rooms and office areas influence performance and mood? In which tasks does the LFN affect performance? What relation is there between self-rated sensitivity to noise in general and to LFN?

2 - METHODS
Subjects: 19 female and 13 male students, with normal hearing and an average age of 24.3, were recruited and categorised as sensitive or non-sensitive to low frequency noise (LFN) and sensitive or non-sensitive to noise in general (NG). To assess sensitivity to LFN two questions "are you sensitive to LFN" and "I am sensitive to rumbling noise from ventilation systems" were used, and to assess sensitivity to NG the question "are you sensitive to noise in general" were used together with the total number of points scored in Weinstein's noise sensitivity evaluation questionnaire [4].
Noise exposure: The subjects were exposed to two types of noises (figure 1), both at a level of 40 dBA. The reference noise (ref. noise) was recorded from a ventilation installation and had a rather flat mid-frequency spectrum. To obtain a LFN, sound pressure levels in the frequency region of 31.5 to 125 Hz were increased using a digitalised sound processor system [Aladdin interactive work-bench, Nyvalla DSP Stockholm]. Furthermore, a tone at 31.5 Hz was amplitude-modulated with an amplitude frequency of 2 Hz.

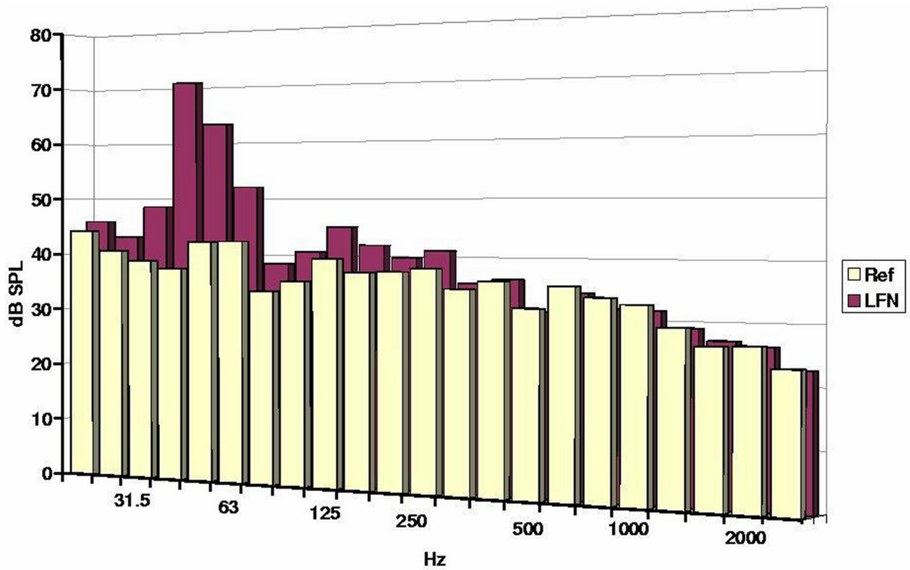

Figure 1: Third octave band sound pressure levels of reference and low frequency noise.

Performance tests and questionnaires: Four performance tests were used. Test I was a simple reaction time test and test II a short-term memory test, performed together with a secondary test previously used by Persson Waye et al 1997. Test III was a proof reading test [5] where the subject read a text on paper and marked errors in the text. Test IV was a computerised verbal grammatical reasoning test, translated into Swedish [6]. Before and after the test session a questionnaire evaluating moods [7] was completed. After the test session, the subject filled out a questionnaire evaluating subjective work impairment, annoyance due to the noise present during the test and presence of symptoms experienced during and after the experiment. To assess stress, saliva samples were taken and the amount of cortisol determined. These latter data will be reported elsewhere.
Test chamber: The experiment was performed in a 24 m^2 room, furnished as an office. The sound was emitted from four loudspeakers, placed in each corner and hidden behind curtains. To amplify the LFN, a subwoofer was used (ace-bass B2-50). The background noise from the test chamber ventilation was less than 22 dBA, and the sound pressure levels for the frequencies below 160 Hz were below the threshold of normal hearing [8].
Experimental design and procedure: The experiment had a 2 (noises) * 2 (phases) * 2 (sensitivity groups) factorial design with repeated measurement in the first two factors and independent groups in the sensitivity factor. In the analyses of test I and IV a fourth factor, time blocks within the task, was added. On a separate occasion the subjects learned the procedures and practiced on short versions of the performance tests for about one hour with the ref. noise, at 35 dBA, and the importance to work as fast and correctly as possible was emphasised. The main test consisted of two sessions, 2.5-3 hours each, on separate days and always in the afternoon. Half of the subjects started with the ref.noise and the other half with the LFN. During each phase (A and B) in the test session, the subjects worked with the four performance tests. To minimise subjective influence due to attitude to noise, motivation and own expectations before the test sessions, the written and verbal information about the experiment did not explicitly refer to noise exposure.
Analysis and statistical methods: Analyses of variance were performed to evaluate the influence of noise exposure, time, subjective sensitivity and their interactions on the different performance tests and subjective ratings. The p-values are based on degrees of freedom corrected with Greenhouse-Geisser epsilon, when appropriate. The statistical analyses were carried out using SPSS. Correlations of subjective estimations were carried out using Pearson's correlation analysis. All tests were two-sided and a p-value of <0.05 was considered as statistically significant.

3 - RESULTS

Performance tests: No differences between noises were found for the *simple reaction time test*, the *short term memory test* or the *bulb test*. In the *proof reading test*, the interaction between noise and phase ($F(1,31)= 10.069$, $p<0.005$) shows that the *number of erroneous corrections per read lines* was lower in phase B during LFN but not during the ref.noise. No significant effect was found for *number of correct* *markings per line*. An interaction between noise and phase was also found for the *total markings* (correct and erroneous) per line (F(1,31)=7.018, p<0.05).

		Reference noise		**Low freq. Noise**	
	Phase A	**Phase B**	**Phase A**	**Phase B**	
Number of lines read	**All subjects**	**134**	**133**	**136**	**137**
	Sensitive LFN *	126	131	132	129
	Non-sensitive LFN*	144	136	141	148
	Sensitive NG*	128	135	139	134
	Non-sensitive NG*	139	132	133	140
Erroneous corrections/line	**All subjects***	**0.06**	**0.06**	**0.06**	**0.04**
	Sensitive LFN	0.05	0.05	0.06	0.04
	Non-sensitive LFN	0.06	0.07	0.06	0.04
	Sensitive NG	0.05	0.05	0.05	0.04
	Non-sensitive NG	0.06	0.07	0.06	0.05
Total markings/line	**All subjects***	**0.13**	**0.13**	**0.13**	**0.10**
	Sensitive LFN*	0.13	0.12	0.13	0.10
	Non-sensitive LFN*	0.13	0.14	0.13	0.11
	Sensitive NG	0.12	0.12	0.12	0.11
	Non-sensitive NG	0.13	0.13	0.14	0.09

Table 1: The results from the proof reading test (* sign p<0.05).

An interaction between noise, phase and LFN sensitivity (F(1,30)= 5.306, p<0.05) showed that number of lines differed between noises and phases. Also for subjects classified into sensitivity to NG, an interaction between noise, phase and sensitivity was present (F(1,30)=7.976, p<0.01), but the pattern was less pronounced.
The results from the *verbal grammatical reasoning test* demonstrated no difference in total response time between noise exposures for phase A. The mean response time was shorter during phase B as compared to phase A in both noise conditions, (3704 versus 3924 ms, F(1,31)=9.014, p<0.01) but the decrease of response time in phase B was less pronounced during LFN. The interaction between noise and phase was significant (F(1,31)=5.750, p<0.05).

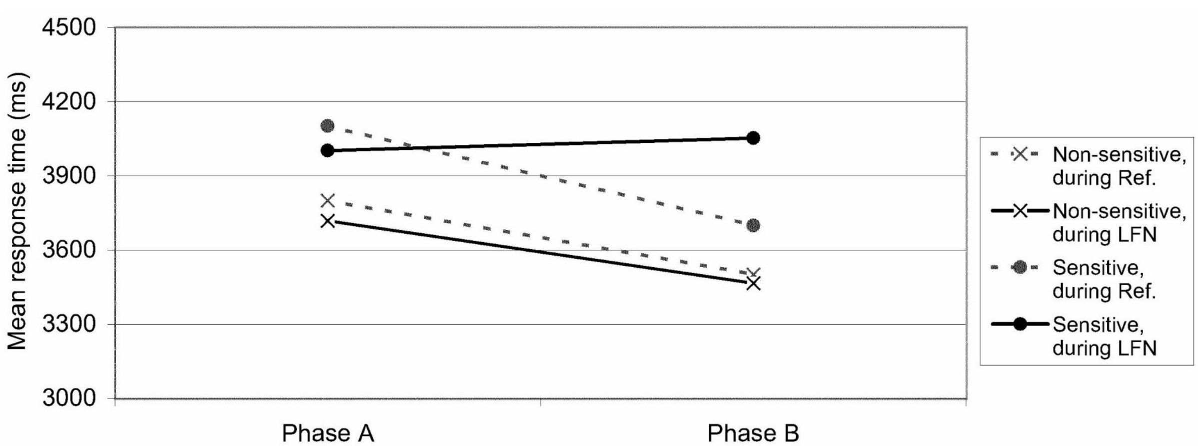

Figure 2: Response times (ms) in the different parts of phase B of the verbal grammatical reasoning test during low frequency noise and ref.noise related to sensitivity to LFN.

Subjects sensitive to LFN had on average a similar response time between noises in phase A. Figure 2 shows that the difference in response time during LFN and ref.noise was larger in phase B, and a tendency to a three-way interaction between sensitivity to LFN, noise and phase was found (F(1,30)=3.319, p=0.078). For subjects classified as sensitive to NG, no difference between the noise conditions was detected.

Subjective estimations: The LFN was rated as more *annoying* then the ref. noise (2.47 versus 2.00; F(1,31)=9.922, p<0.005). Subjects sensitive to LFN were more annoyed by LFN than by the ref. noise (3.1 versus 2.3), while non-sensitive subjects reported on average the same annoyance after both noises (1.6), (F(1,30)=6.534, p<0.05). No significant difference between noises was found for subjects classified into sensitivity to NG. The LFN was also considered to *impair the working capacity* more than the ref. noise (3.4 versus 2.6; F(1,31)=4.649, p<0.05).

Annoyance due to LFN was correlated to a feeling of pressure on the head (r_{xy}=0.664, p<0.001), tiredness (r_{xy}=0.519, p<0.005), dizziness (r_{xy}=0.519, p<0.005) and lack of concentration (r_{xy} = 0.537, p<0.005). Ref. noise annoyance was only correlated to nausea (r_{xy}=0.522, p<0.005). Performance impairment due to LFN exposure was significantly correlated to a feeling of pressure on the head (r_{xy}=0.479, p<0.01) and tiredness (r_{xy}=0.479, p<0.01). No significant correlation between noise impairment due to ref. noise and symptoms was found.

4 - CONCLUSIONS

The results indicate that low frequency noise at levels normally occurring in office and control rooms could negatively influence performance in more demanding tests, while the easier tests remain unaffected. It also points to the important of classifying subjects into noise sensitivity.

ACKNOWLEDGEMENTS

The project was supported by funds from Swedish Council for Work Life research (grant nr 1998-06-08) and the project is also part of a network-program for occupational health research funded by the Swedish Working Life Institute. We gratefully acknowledge the valuable research assistance by Agneta Agge and technical assistance by Martin Björkman.

REFERENCES

1. **Nagai N, Matsumoto M, Yamasumi Y, Shiraishi T, Ishimura K, Matsumoto K, Miyshita K, Takeda S**, *Process and emergence on the effects of infrasonic and low frequency noise on inhabitants*, J Low Freq Noise Vibr; 8:87-99, 1989

2. **Persson Waye K and Rylander R**, *The extent of annoyance and long term effects among persons exposed to LFN in the home environment*, accepted for publication in J Sound and Vibr, 2000

3. **Persson Waye K, Björkman M, Hellström P-A and Rylander R**, *Acute effects of LFN in relation to susceptibility to LFN*, submitted to J Sound Vibr.

4. **Weinstein N D**, *Individual differences in reactions to noise: A longitudinal study in a college dormitory*, J Appl Psychol; 63: pp 458-466, 1978

5. **Landström U, Byström M, Kjellberg A and Nordström B**, *Performance and annoyance during exposure for amplitude-modulated noise at different noise levels*, National Institute of Occupational Health. Report 1997:15

6. **Baddeley A D**, *A 3min reasoning test based on grammatical transformation*, Psychon Sci 10, pp 341-342, 1968

7. **Sjöberg L, Svensson E and Persson L O**, *The measurement of mood*, Scand J Psychol 20, pp 1-18, 1979

8. ISO 389-7:1996, Acoustics Reference zero for the calibration of audiometric equipment Part 7: Reference threshold of hearing under free-field and diffuse-field listening conditions.