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DOES LOW FREQUENCY NOISE DURING WORK INDUCE STRESS?

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ABSTRACT
To study the possible interference of low frequency noise on stress experienced during performance, test persons classified into noise sensitivity, worked with different performance tests in a low frequency or middle frequency ventilation noise, both at a level of 40 dB LAeq. The effects were evaluated as changes in cortisol in saliva, taken at different times before and during the test. The normal circardian downward drift of cortisol was not significantly modulated by either noise condition or subject-sensitivity to noise, alone. However, the decline in cortisol was significantly less for subjects who were both sensitive to noise *and* exposed to low frequency noise. The result also point towards a correlation between base-corrected cortisol during the experimental period and base-corrected stress reporting during the low frequency noise condition.

1 - BACKGROUND
Data show that low frequency noise (<200 Hz,) has effect characteristics that are different from other environmental noises at comparable levels [1,2]. The exposure to low frequency noise during work and recreation has been found to cause general annoyance [3,4] as well as impaired response time in performance tests among persons sensitive to low frequency noise [4]. Many modern working conditions involve a high element of unpredictability, selective attention, and processing of a high load of information. The knowledge on how such work demands are affected by the extra loading of low frequency noise emitted from e.g. ventilation/ air conditioning systems, is scarce, but it is plausible that the noise load would put an extra strain on the individual that could result in a stress response. The results from a study of performance demonstrated that low frequency noise interfered with mentally demanding verbal tests [5]. The subjects reported a higher degree of annoyance and work impairment when working in low frequency noise, and subjects classified as sensitive to low frequency noise or to noise in general, were at highest risk. The aim of this study was to investigate whether low frequency noise during work would lead to subjective stress and result in increased secretion cortisol levels in saliva. Elevations in cortisol concentration reflect together with cardiovascular and other neuroendocrine measures various aspects of the stressfulness of the individual's interaction with the environment [6].
The subjects performed four performance tests during exposure to a low frequency noise or a reference noise at the same sound level. Part of the experiment describing the effects on performance test has been reported previously [5].

2 - MATERIAL AND METHODS
<u>Noise exposure</u>: Two types of ventilation noises were used. The reference noise (Ref) was recorded from a ventilation installation and had a mid-frequency spectrum. For the low frequency noise (LFN), sound

pressure levels in the frequency region of 31.5 to 125 Hz were added to the ventilation noise using a digitalised sound processor system (Aladdin interactive workbench, Nyvalla DSP Stockholm, Sweden). Furthermore, a tone at 31.5 Hz was amplitude-modulated with an amplitude frequency of 2 Hz. Both noises had a level of 40 dBA (Figure 1). The experiment was performed in a 24 m^2 room, furnished as an office as described previously [5].

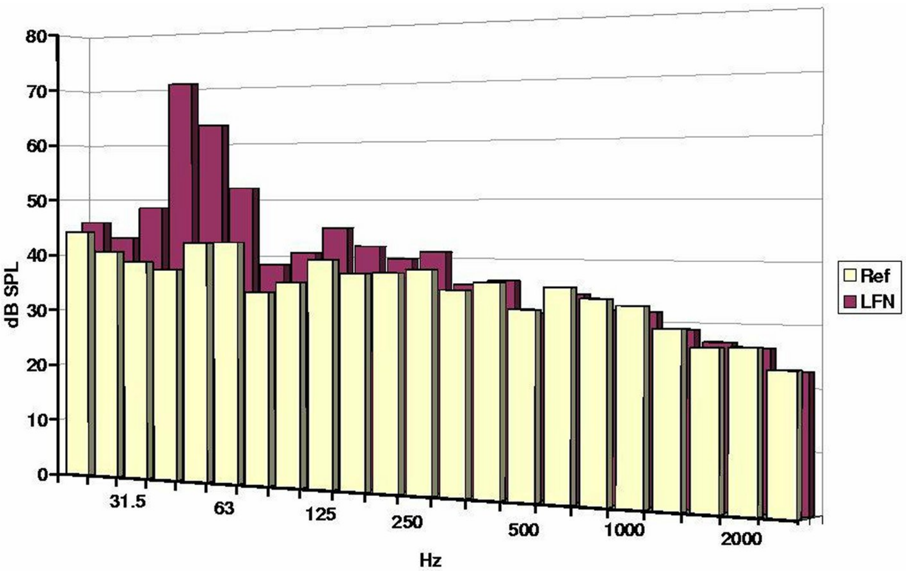

Figure 1: Third octave band sound pressure levels of reference (light coloured bars) and low frequency noise used during the performance tests.

Experimental procedure: The test consisted of two sessions, 2.5-3 hours each, on separate days and always in the afternoon. The subjects worked with four performance tests twice (phase A and B) and were instructed to work as correct and fast as possible. Half of the subjects started with the Ref and the other half with the LFN.
Subjects: 19 female and 13 male subjects with normal hearing and an average age of 24.3 years participated. The subjects were classified as sensitive or not sensitive to noise in general using a questionnaire as described previously [5].
Determination of cortisol: Saliva samples were taken by asking the test persons to chew on a cotton salivette (Sarstedt Ltd, UK) for 3 minutes, after which it was frozen at $-70°C$ until analysed. To allow for a proper baseline level, the subjects came to the laboratory and relaxed for 20 minutes before the first sample was taken. During phase A, four samples were taken with approximately 10 minutes intervals. A final sample (post base) was taken at the end of the second session (after 160 min). In total, six samples were taken, of which the first sample will serve as a baseline value, the second to the fifth sample will reflect stress during the different tasks and the sixth sample will serve as a post base at the end of the test session.
Suspensions were prepared from the saliva and cortisol were determined by a method previously described [7].
Subjective ratings: During the test session and after the saliva samples 1, 2, 3, 4 and 6, the subjects evaluated stress and energy by a questionnaire [8]. When the test session was completed, subjects answered a questionnaire evaluating annoyance due to noise and perceived impairment of the tasks due to noise. There were five response alternatives ranging from "not at all" to "extremely".
Statistical analysis: Analysis was carried out by a 3×2×2 ANOVA. Two factors were within-subjects: Period (base, mean of measures during the experiment, and post-base) and Noise Condition (LFN and Ref). Sensitivity to Noise (high and low) was a between-subjects factor. Analysis was performed on cortisol values expressed as square-roots of raw data to counteract initially skewed distributions. Correction did not change any significance decision. Primary tests of hypotheses were carried out using orthogonal comparisons of the experimental period compared to the mean of both base values, and then a comparison of both individual base values. In view of the known circadian downward drift of cortisol during the day (see below), there is a need to compare observed cortisol values during the experimental period with an average of before and after values. In the analysis of the relationship between cortisol levels and subjective stress rating, the values were analysed in relations to their initial values (base values). The

statistical analyses were done using SPSS [SPSS base 7.5 for Windows]. All tests were two-sided and a p-value of <0.05 was considered as statistically significant.

3 - RESULTS

Cortisol analysis: There was a highly significant main effect of Period ($F=16.43$; $df=2,56$; $p<.001$). Means for all subjects, aggregated over the two noise conditions, was 2.3 for base, 1.9 during experimental period and 1.7 for post-base. In accordance with expectation based on known circadian effects, cortisol was significantly decreased at the last sampling point compared to the first (base) point ($t=4.70$; $p<.001$). There were no significant interactive effects of either noise nor sensitivity factors in relation to the cortisol pattern over time. In particular, cortisol levels (compared to the average of base and final values) were not significantly higher in the low frequency condition, nor among noise-sensitive subjects. However, a significant 3-way interaction between noise condition, sensitivity of subject, and period was obtained for this key comparison ($t=2.49$; $p<.02$).

Consequent analysis of simple effects indicated that in the LFN condition, noise-sensitive subjects maintained higher cortisol levels, relative to base values, during the experimental period than non-sensitive subjects ($t=2.03$; $p<.05$). In the Ref condition, no difference was seen between sensitive and non-sensitive subjects. Thus, higher relative cortisol values during the experiment are associated with the combination of being noise sensitive and being in a LFN condition. The means for sensitive and non-sensitive subjects in the LFN condition are plotted in Figure 2.

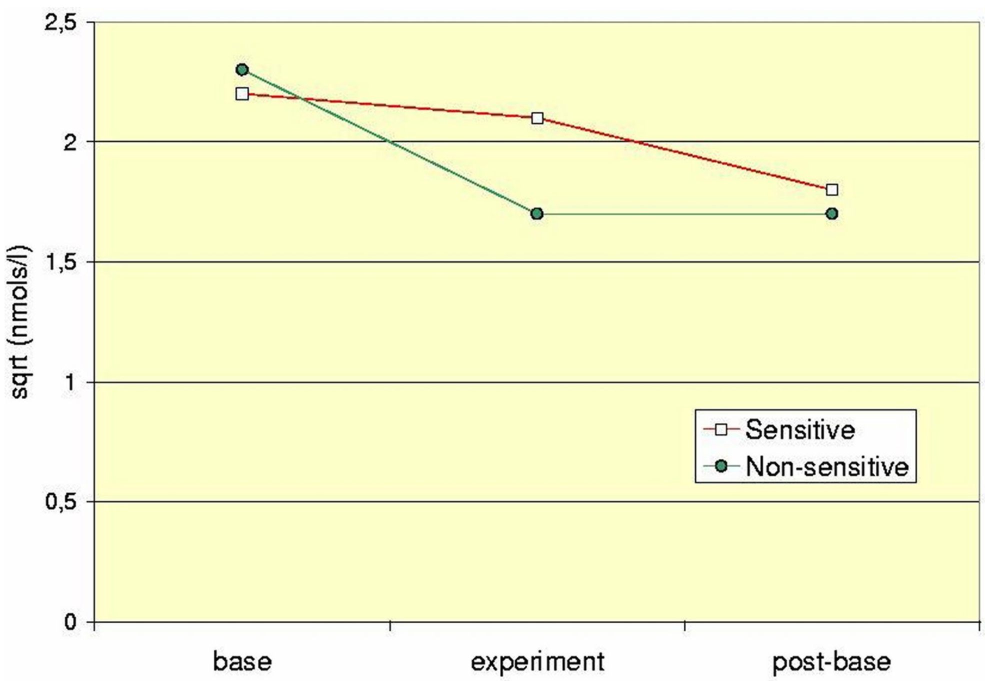

Figure 2: Average values of cortisol during base, experimental period and post-base for subjects sensitive and non-sensitive to noise during the low frequency noise exposure.

Subjective estimations: Orthogonal comparisons showed that stress was elevated during experimental periods compared to base points ($t=6.57$; $p<.001$), but also still elevated post-base compared to base ($t=4.01$; $p<.001$). Stress reports were relatively high on the first trial measure ($M=2.3$; $se=.13$), fell for the middle trial measure ($M=1.8$; $se=.13$), but then very significantly increased ($M=2.5$; $se=.15$) for the final trial measure ($t=6.20$; $p<.001$). There were no significant effects of noise or noise sensitivity. The LFN was on average rated as more annoying then the Ref ($M=2.47$ versus $M=2.00$; $F(1,31)=9.922$, $p<0.005$). No significant difference between noises was found when the subjects were classified into general noise sensitivity. LFN was on average considered to impair the working capacity more than the Ref ($M=3.4$ versus $M=2.6$; $F(1,31)=4.649$, $p<0.05$). No significant difference between noises was found when the subjects were classified into general noise sensitivity.

Correlational analysis of cortisol and stress reporting: In order to examine a fundamental assumption of the study that cortisol activity reflects stress, we computed base corrected cortisol and self-report stress scores for both noise conditions, expressing experimental period as percentage above or below mean base.

The correlation between stress and cortisol for both noise conditions was positive in direction. However, the correlation was moderately large and statistically significant for the LFN condition only (r= 0.40; n=27; p<.05). The correlation for the Ref was r= 0.19 and not significant.

4 - CONCLUSION

The normal circardian downward drift of cortisol was not significantly modulated by either noise condition or subject-sensitivity to noise, alone. Higher cortisol values were however associated with the combination of being noise sensitive and being in a low frequency noise condition. In this same condition, cortisol was related to subjective feelings of stress.

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