IS A "PLEASANT" LOW FREQUENCY NOISE ALSO LESS ANNOYING?

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Introduction Noises with a dominating content of low frequencies (20-200 Hz, LFN) are commonly found in working environments. Work efficiency and work quality has in two previous studies [1;2] been found to be impaired to a larger degree when working in a LFN ventilation noise, compared to when working in a reference noise with flat frequency spectra at the same A-weighted noise level. Previous studies indicate that different sound characters in LFN are of importance for the negative effects and a better knowledge of these parameters could lead to improved methods of assessing effects due to LFN, compared to only be using A-weighted noise levels. This study focuses on the sound characters frequency balance (i.e. the relative content of high and low frequencies, or the slope of the frequency spectra) and modulation frequency. The subjects were categorised as sensitive to low frequency noise, in accordance with [1;2]. The *aim of part A* was to evaluate the influence of frequency balance and modulation frequency on subjects' perception of a pleasant LFN. The *aim of part B* was to evaluate three pleasant LFNs, based on the results from part A, and evaluate their effect on annoyance and performance, compared to the initial LFN and a reference noise with flat frequency spectra.

Methods: Part A 30 subjects adjusted interactively an initial LFN to be as pleasant as possible by varying the two parameters modulation frequency (mod-freq) and frequency balance (freq-bal). A ventilation noise of a predominantly low frequency character was used as the initial noise (initial LFN). The same noise has been used in previous studies evaluating effects on annoyance and performance [3;1;2]. For the adjustments of the mod-freq (I), the subjects could vary the mod-freq between 10 Hz and 0.1 Hz. For the adjustments of the freq-bal, the subjects varied the content of high and low frequencies in a predefined range. These adjustments were either performed by varying the content of low and high frequencies at a constant A-weighted level at 45 dBA (II and III). Or, the adjustments were performed with a constant content of low frequencies and only the content of high frequencies could be altered. In these latter adjustments (IV and V), when increasing the high frequencies the noise level could increase from 45 dBA to 65 dBA. The adjustments were done with (II and IV) or without (III and V) the initial mod-freq at 2 Hz. The subjects were instructed to adjust the noise to be as pleasant, or as least unpleasant as possible. All adjustments were performed four times in a randomised order, each adjustment starting alternatively at the highest or the lowest value in the predefined ranges.

Methods: Part B 63 subjects worked for 1 hour during exposure to two out of five noises at 45 dBA. Three of the noises were adjusted to be more pleasant, in accordance with the results from part A, having a pleasant freq-bal, a pleasant mod-freq or both a pleasant freq-bal and a pleasant mod-freq. During the noise exposure, the subjects worked with three demanding performance tasks, and to generate a high workload, they were instructed to work rapidly and correctly. Annoyance was evaluated using questionnaire. The results were compared to the

initial LFN and a reference noise with flat frequency spectra. Data have been collected but not analysed. The results will be presented at the conference.

Results: Part A All adjustments of the *mod-freq* differed from the mod-freq of 2 Hz in the initial LFN ($p<0.01$). Some subjects were affected by the starting value; they chose a low mod-freq when the adjustments started at the minimum value and a high mod-freq when the adjustments started at the maximum value. Due to this, calculating a mean or a median value would not be an appropriate way of describing the results. When studying the results more closely, two different groups appeared. One group preferring a higher (mean 9.1 Hz) and one group preferring a lower (mean 0.4 Hz) mod-freq compared to the initial LFN. The middle range was however avoided by most subjects. In the four different adjustments of the *freq-bal*, the subjects preferred a lower relative content of low frequencies ($p<0.001$) compared to a higher content of high frequencies, but only as long as the initial noise contained modulations ($p=0.057$). When the last two adjustments were carried out, where an increased content of high frequencies did not affect the content of low frequencies, but the noise level could increase, the subjects only chose a somewhat higher noise level (median noise level 45.3 dBA, or 45.1 dBA when the noise did not contain modulations).

Discussion: Part A When the authors listened to the two different *mod-freq,* both of the subjects choices seem to lead to less perceivable modulations. The avoidance of the middle range in evaluation pleasantness is in accordance with previous studies of perception [4] and annoyance [5]. Thus the presence of modulations has an important impact on the perception of a pleasant LFN. The resulting sounds from the adjustments of the *freq-bal* at a constant noise level showed that the subjects preferred a noise with a lower content of low frequencies. The results were however dependent on whether the sound comprised modulations or not. Thus, the result was in agreement with the adjustments of the mod-freq showing that the occurrence of modulations had a significant effect on the results, supporting the hypothesis that the presence of perceivable modulations in a LFN is of great importance for the judgement of pleasantness. A comparison between the adjusted freq-bal with previous findings evaluating the importance of slope for annoyance will be reported elsewhere.

Concluding comment To make the initial LFN more pleasant, the subjects chose either a higher or a lower mod-freq, indicating that none or a very low mod-freq was the most pleasant alternative. Furthermore, the subjects preferred a lower content of low frequencies compared to the initial LFN. When the adjustments of the freq-bal were carried out without the original mod-freq on 2 Hz, or when the noise level could be altered, the results were less clear.

Keywords. Low frequency noise, sound characteristics, performance, annoyance.

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