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Is a “pleasant” low-frequency noise also less annoying?

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1. Background

Noise sources with a dominant content of low frequencies (20–200 Hz) are found in many occupational environments. Previous studies indicate that certain sound characteristics in such low-frequency noise (LFN) may be important for how LFN affects humans. 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 annoyance and performance after exposure to the pleasant LFNs, obtained in part A, and to compare the results with exposure to the original LFN and a reference noise with flat frequency spectra.

2. Methods

In part A, 30 subjects interactively varied (1) the amplitude modulation frequency of a 31.5 Hz tone (adjustment I) and (2) the balance of high and low frequencies (adjustments II, III, IV & V) in a LFN, with the objective to create a more pleasant, or a less unpleasant, LFN. The original LFN was a ventilation noise of a predominantly low-frequency character compared to when working in a flat frequency ventilation noise at the same A-weighted sound pressure level (SPL). The same LFN has previously been found to impair work efficiency and work quality to a larger degree compared to when working in a reference noise with flat frequency spectra [1,2]. The amplitude modulation frequency could be changed between 0.1 and 10 Hz of the amplitude

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modulated 31.5 Hz tone. The frequency balance could be varied in a predefined range, resulting in a varying content of high and low frequencies. These adjustments were done with (II, IV) or without (III, V) the initial modulation frequency at 2 Hz. The adjustments were either performed by varying the content of low and high frequencies at a constant A-weighted SPL at 45 dB (II, III), or the A-weighted SPL could increase from 45 dB to 65 dB (IV, V). These latter results (IV, V), together with a discussion of previous findings evaluating the importance of slope for annoyance, are reported elsewhere [3]. The subjects were told to adjust the original LFN to be as pleasant, or at least as little unpleasant as possible. All adjustments were performed four times in a randomised order, starting alternatively at the highest or the lowest value in the predefined range. In part B, 63 subjects worked with three demanding performance tasks during 1 h of noise exposure at an A-weighted SPL of 45 dB. Five exposure noises were used in a within-subject design. Three of the noises were adjusted to be more pleasant LFNs in accordance with the results from part A: LFN with a pleasant frequency balance (pleasant-bal), LFN with a pleasant modulation frequency (pleasant-mod) or LFN with both a pleasant frequency balance and a pleasant modulation frequency (pleasant-both). The original LFN and a reference noise with flat frequency spectra were also included. Subjective reports were evaluated using a questionnaire. This paper comprises the results from three of the questions: Did the noise in the test session impair or improve your work capacity? (seven response alternatives ranging from (1) “major improvement” to (7) “major impairments”). How annoying was the noise during the test session? (five response alternatives ranging from (1) “not at all” to (5) “extremely”). Would you like to change the noise environment you have been working in? (five response alternatives ranging from (1) “not at all” to (5) “extremely”). The results from the performance tasks will be reported elsewhere. In both parts, the subjects were categorised as sensitive to LFN, in accordance with previously reported criteria [1,2].

3. Results

3.1. Part A

All four adjustments of the modulation frequency differed from the modulation frequency of 2 Hz in the original LFN ($Z = -3.663$, $p < 0.001$; $Z = -3.669$, $p < 0.001$; $Z = -3.799$, $p < 0.001$; $Z = -2.710$, $p < 0.01$). The results suggest that the subjects preferred either a higher (mean 9.1 Hz) or a lower (mean 0.4 Hz) modulation frequency as compared to that of the original LFN. Most subjects avoided the middle range. In adjustment II of the frequency balance, a significantly lower content of frequencies below 500 Hz was preferred compared to the original LFN comprising modulations ($Z = -4.135$, $p < 0.001$). A less clear result was found in adjustment III, i.e. when the LFN did not comprise modulations ($Z = -1.903$, $p = 0.057$).

3.2. Part B

Table 1 shows the results from the three questions. No significant differences between the original LFN and the other noises were found when the subjects rated if the noise had improved or impaired their work capacity. Annoyance was judged to be somewhat higher for the original

Table 1

Average mean for the ratings given on the three questions.

	Did the noise improve or impair your work capacity?	How annoying was the noise during the test session?	Would you like to change the noise you have been working in?
Pleasant-mod vs. original LFN	5.0	2.4**	3.0*
Pleasant-bal vs. original LFN	5.6	3.1	3.9
Pleasant-both vs. original LFN	5.4	3.1**	3.6*
Reference noise vs. original LFN	5.3	2.8	3.0
	5.9	3.3	3.7

* $p < 0.05$.** $p < 0.10$.

LFN compared to the LFN with pleasant-mod and the LFN with pleasant-both. These differences did, however, not reach statistical significance ($Z = -0.575$, $p = 0.070$ and $Z = -1.811$, $p = 0.070$, respectively). When exposed to the original LFN, subjects reported to a significantly higher degree that they wanted to change the noise environment, compared to the LFN with pleasant-mod ($Z = -2.310$, $p = 0.021$), the LFN with pleasant-both ($Z = -1.983$, $p = 0.047$) and the reference noise ($Z = -2.157$, $p = 0.031$).

4. Comments

The results suggest that the presence of modulations are of importance for whether a LFN is perceived as pleasant or not. A LFN with a pleasant modulation frequency was rated as less needed to be changed and as somewhat less annoying. A LFN with a lower content of low frequencies was perceived as more pleasant, but the frequency balance was of less importance if the LFN did not contain perceivable modulations. The combination of a LFN with both a pleasant modulation frequency and a pleasant frequency balance was rated as less needed to be changed and as somewhat less annoying.

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