The subjective influence of the LFN combined with pink and white noise

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1 Introduction

Low frequency noise (LFN) is a common source of annoyance at home and in the work environment. The exact reason why a certain part of people has serious problems with LFN is unknown, and the relevant studies have been done on the hearing aspect [1], and the brain [2]. One direct way to reduce the influence of LFN on people is to find the noise source and remove it, which is sometimes difficult because it is impossible to identify the location of LFN. An indirect method, sound adjustment [3] for example, seems to be more feasible. Many studies suggested that the subjective annoyance of LFN can be influenced by adding some additional sounds [3, 4], and the presence of higher frequency sounds has been found effective to reduce the influence of LFN [5].

2 Materials and Methods

2.1 Subjects and experiment conditions:

Sixteen students (5 male and 11 females) with normal hearing from Capital Normal University were recruited as subjects in the experiment. The age of the subjects was 20 or 21. The playback equipment in the experiment was loudspeakers.

2.2 Noise samples:

There were 4 original low frequency noise samples. LFN1 and LFN2 were recording signals. LFN3 was the Brown Noise through Butterworth low pass filter with the cut-off frequency at 80Hz and the order 10, and LFN4 was obtained with the same filter but with 160Hz as the cut-off frequency. The SPL of the original LFNs was 45dBA.

The signals as the additional components combined with LFN were bandwidth pink noise (PN) and white noise (WN). The SPLs of these noises were 15dB, 20dB and 25dB, and the bandwidths frequency ranges are listed in Table 1. There were six independent sub-tests (Table 2). Previous study suggested that 5s is an appropriate duration of sound exposure [6]. Therefore the duration of each noise sample was 5s, with an interval of 3s.

Table 1: The bandwidth frequency ranges of the additional pink noise and white noise

250-500Hz	250-4KHz	1K-2KHz
250-1KHz	500-1KHz	2K-4KHz
250-2KHz	500-2KHz	4K-8KHz

Table 2: The information of the six sub-tests in the study

Test 1	Test 2	Test 3
LFN1 + Pink noise	LFN1 + White noise	LFN2 + Pink noise
Test 4	Test 5	Test 6
LFN3 + Pink noise	LFN4 + Pink noise	LFN4 + White noise

2.3 Test method

First, the subjects have answered the noise sensitive questionnaire (NoiSeQ) [7] to check their noise sensitivity. There were 35 items in the questionnaire, with a four-level rating scale. The sum of the rating values of all the items was calculated as the characteristic value for the global noise sensitivity.

The magnitude estimation method was adopted in the study as the subjective evaluation method. There were seven annoyance levels (from 1 to 7), 1 was the lowest and 7 was for the highest. At the end the subjects were asked whether they had a headache, earache or any other physiological and psychological feelings.

3 Results

16 subjects were classified into two groups; 4 people were sensitive to noise (SG) (with a score ≥70), and 12 were not sensitive to noise (Non-SG) (with a score <70). It was noted that all 4 subjects with high noise sensitivity were female.

The average annoyance level values of the subjects who have passed the reliability test were calculated as the SAV result for each noise stimulus (Table 3). Then the correlation coefficient between SAV and PAV (according to the semi-theoretical formulas of Zwicker and Fastl's theory) was calculated.

Table 3: The average SAV results

	Non -SG	SG		Non -SG	SG
LFN1-PN	4.48	**4.18**	LFN3-PN	4.66	**4.23**
LFN1-WN	**4.38**	4.75	LFN4-PN	**4.36**	4.65
LFN2-PN	4.66	**4.31**	LFN4-WN	**4.31**	4.58

The Independent-Samples T test was calculated to check whether there was a significant difference between the SAV of the SG and the Non-SG. The p-values in the results were all lower than 0.01. Figure 1 gives two examples of the results. About half of the subjects have reported headaches and earache, some felt nausea, dizziness and dysphoria. The sub-test LFN4 with pink noise was the penultimate test, and the uncomfortable feelings of the subjects might have caused the inconsistency in the results.

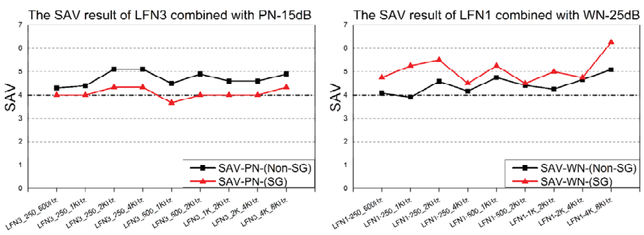

Figure 1: The example of the SAV results of two noise-sensitive groups

The difference between the SAV of LFN when combined with pink noise and with white noise was also checked for LFN1 and LFN4 with the paired-Samples T test. The Figure 2 shows that the SAVs of LFN1 combined with pink noise and with white noise were almost the same for the Non-SG, but for the SG the SAV of LFN1 combined with pink noise was significant lower than the SAV of LFN1 combined with white noise.

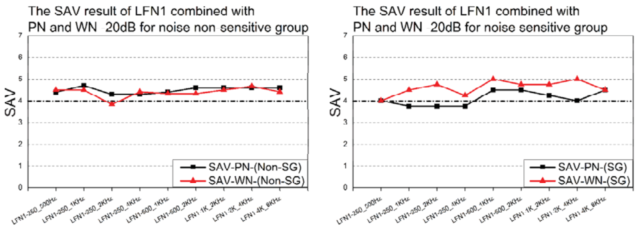

Figure 2: The SAV results of adding pink noise and white noise for the two noise-sensitivity groups

The aim of the experiment was to identify the subjective changes caused by LFN combined with pink noise and white noise, and to check whether the SAV decreases because of the additional components. Therefore the combinations with an SAV lower than “4” were summarized. The results showed a tendency for only pink noise as an additional component combined with LFN to decrease negative annoyance feelings caused by LFN for subjects belonging to the SG, whereas for the Non-SG subjects adding either pink noise or white noise to LFN has annoyance reduction effects.

4 Conclusions

In this paper, an indirect method for reducing annoyance caused by LFN was introduced. 4 different original LFNs were combined with two types of additional sounds, pink noise and white noise, to observe variation in the subjective annoyance feeling. The main findings are summarized as follows:

1. There was a significant difference between the SAV for the SG and the Non-SG in all six sub-tests, which indicated that people with different noise sensitivity would have different subjective annoyance feelings caused by LFN combined with pink noise or white noise. The NoiSeQ used here is suitable for the LFN sensitivity classification.

2. There was an obvious difference between the SAV of LFN combined with pink noise and with white noise for subjects belonged to the SG, whereas the SAV of the Non-SG for two types of noise combinations were almost the same. And the SAV of some combination of LFN with pink noise were found to be lower than the SAV of the original LFN, which mostly applied to the SG. This result indicates that people with high noise sensitivity can be influenced more positively than people with normal noise sensitivity, when bandwidth pink noise is used as the additional components. And it also implies that the indirect annoyance reducing method may not be the best way to decrease the negative annoyance feelings caused by LFN for people with normal noise sensitivity.

3. The bandwidth pink noise or white noise with lower SAVs were mostly in the middle frequency range, such as 250-500Hz, 250-1KHz, and 500-1 KHz, which was similar to the result in [4]. The SAVs of LFN combined with bandwidth noise in a higher frequency range were mostly higher than the SAVs of the original LFN. According to [4] the reason would be the new negative annoyance feelings caused by the additional higher frequency components.

4. The PAVs were found to have a significant correlation with SAV in a few noise combinations, but there was no obvious pattern. This indicates that the PAV may be not suitable to predict or estimate the SAV of LFN combined with pink noise or white noise.

The above conclusions indicate that the indirect method to decrease the negative annoyance feelings cause by LFN is feasible, and in particular that it is more suitable for people with high noise sensitivity. Pink noise in the middle frequency range with appropriate SPL could be used as the additional components in the indirect method. No significant gender difference was found in this study. However, the 4 subjects with higher noise sensitivity were all female, which could imply that females are more sensitive to LFN than males, but it needs future research to prove. Looking for other kinds of sounds to use in the indirect method and considering other types of LFN could be a research direction in the future.

References:

[1] Krahé, D.: Refection of LFN perception on an auditory model. NAG/DAGA International Conference on Acoustics, Rotterdam, 2009

[2] Krahé, D. and Weigler, T.: Reaction in the brain to low-frequency noise. AIA-DAGA 2013 Merano. 2013

[3] Li, Z.: Study on acoustical simulation and adjustment methods of subjective perception and objective law of electroencephalogram variation under noise exposure. Zhejiang University, 2012

[4]. Di, G.Q., Li, Zh.G., Zhang, B.J., Shi, Y.: Adjustment on subjective annoyance of low frequency noise by adding additional sound. Journal of Sound and Vibration 330 (2011), 5707-5715

[5] Salt, A.N. and Lichtenhan, J.T.: Perception-based protection from low-frequency sound may not be enough. Proceedings InterNoise. 2012

[6] Otto N., Amman S., Eaton C., et al.: Guidelines for jury evaluations of auto motive sounds. Journal of Sound and Vibration 35(4) (2001), 24-47

[7] Schutte, M., et al.: The development of the noise sensitivity questionnaire. Noise & Health 9(34) (2007), 15-24