



Varying the spectral envelope of air-conditioning sounds to enhance indoor acoustic comfort

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ABSTRACT

Sounds of ceiling mounted air-conditioners were recorded at various conditions of classrooms, offices, and libraries. Sound quality was manipulated by varying spectral envelope of the sounds to investigate its effects on acoustic comfort. Tonal components of the sounds were removed, and the sound pressure levels at 250–630 Hz frequency band were varied to generate experimental sounds using original recordings. Subjective auditory tests were conducted by using paired comparison and semantic differential tests. The results showed that sounds without tonal components were preferred over sounds with tonal components. The subjects had a more favorable impression of the sounds which had a larger energy at 250–630 Hz in cases both with and without tonal components. Statistical analysis showed that both tonality and fluctuation strength play major roles as the sound quality metrics which describe the acoustic comfort from the subjects.

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1. Introduction

Considerable works were made to protect indoor acoustic comfort from outside noises such as road traffic noise. Window systems or building façade design with advanced sound insulation technologies were successfully introduced [1–3]. However, not only the noise sources from outside but also those of inside the living environment should be controlled to achieve real acoustic comfort. Major noise sources of indoor environment are regarded as electric household appliances such as air-conditioner, refrigerator, vacuum cleaners, and so on. Among these appliances, air-conditioners are widely used at classroom, office or residence so that many studies are conducted to reduce the sound level and to enhance the sound quality of air-conditioning sounds [4,5].

This study aims to i) investigate the method of sound quality enhancement of air-conditioning sounds by varying the sound's spectral envelopment while maintaining a constant sound energy in order to determine intrinsic sound quality characteristics, ii) investigate the sensations which evoke acoustic comfort on the sound by applying paired comparison and semantic differential methods, and iii) assess the correlation between subjective responses and sound quality metrics.

In order to clarify the sound quality characteristics which affect the acoustic comfort on the air-conditioning sounds, subjective evaluations were made using sound stimuli for which both the original recording and spectral balance was varied. The quality of the sounds were varied by maintaining or eliminating tonal components at low frequency ranges and increasing or decreasing sound pressure levels at 250–630 Hz.

2. Literature review

It is known that not only reductions of sound pressure level but also an enhancement of the sound quality of the noise itself is needed to improve acoustic comfort to the noises generated by air-conditioners. Efforts have been made by many researchers to determine the sound quality metrics which describe a perception of loudness and/or generate annoyance from the noise so that Zwicker's loudness [6] is reported to be a measure which correlates well with subjective responses. However, recent studies, on other appliances' noise such as household refrigerator or wind turbine, show that acoustic comfort can be varied according to differences of sound quality characteristics, even though the sound energy is the same [7–9]. It is also reported that subjective responses are highly correlated with loudness primarily when the volume of sounds fluctuate, whereas the influence of other parameters appears when the loudness is controlled at about the same value [10].

Several methodologies are proposed to identify subjective attributes on the sound quality of indoor air-conditioning noise

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