Appropriate background noise level regarding speech privacy and annoyance in a train cabin

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Summary
The background noise levels in passenger cars of high-speed trains were investigated in relation to speech privacy and noise annoyance. Auditory experiments were conducted for speech signals with background sounds varying speech to noise ratios (SNR). The results showed that speech privacy decreased considerably and noise annoyance increased as the SNR increased from -6 to -3 dBA. In addition, annoyance increased significantly for the increase of background noise level over 63 dBA. The optimal level of interior noise was suggested as 60-63 dBA for enhancement of acoustic comfort with normal speech level in high speed trains.

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1. Introduction

High-speed train systems are one of the most important modes of public transport in Korea. As the number of passengers of Korea Train eXpress (KTX) has grown, the need for acoustic comfort in passenger cars has increased. Accordingly, many studies of the sound qualities of interior noises in trains have been conducted focusing on noise annoyance [1]. However, in addition to noise caused by the train, passengers are another source of annoying sounds in passenger cars [2]. It is necessary to investigate the interior noise of high-speed trains from the perspectives of both noise annoyance and speech privacy to enhance acoustic comfort in high-speed trains. Thus, this study aims to determine the optimal range of background noise levels considering noise annoyance and speech privacy. Auditory experiments were conducted for varying background noise levels and S/N ratios of speech sound to interior noise.

2. Speech privacy and noise annoyance

2.1 Experimental design

Laboratory experiment was designed to investigate the speech privacy and noise annoyance for the combination of interior noise and conversation sounds. A 5-point scale method was used to determine the optimal background noise and S/N ratio for acoustic comfort in high-speed trains. For background noise, interior noises in a high-speed train were recorded at the seat in the middle of the passenger car using a binaural microphone (B&K, Denmark, Type 4101) and a field recorder (Zoom, Japan, H4N) when the train was running on ballast tracks in open fields at speeds of 100, 200, and 300 km/h. For laboratory experiments, 3s audio samples of the interior noises were excerpted from the recording. There were three interior background noise levels: 60, 63, and 66 dBA at 100, 200, and 300 km/h, respectively. The S/N ratio was varied from -15 to 6 dBA in steps of 3 dBA. In total, 24 cases of combined noises were created. During the auditory experiments, five test sentences were presented to each individual in random order for each of the 24 test situations. Thus, each participant listened to a total of 120 test sentences in random order.

2.2 Procedure

30-university students with normal hearing ability, comprising 21 males and 9 females, participated in the experiment. The experiment was performed in a testing booth (4 m × 3 m) with around 25 dBA of background noise. Individuals were instructed to imagine that they were sitting on a seat in a high-speed train compartment. The sounds were presented to the subjects through a headphone (Sennheiser HD 650) in an auditory test booth.

2.3 Results

Figure 1 shows the percentages of subjects who gave a rating of '4' or '5' on the 5-point rating scale with regard to speech privacy and noise annoyance as functions of the speech-to-noise ratios. It was shown that the percentage of subjects reporting high speech privacy dramatically decreased when the S/N ratio increased from -6 dBA to -3 dBA. More than 70% of subjects reported high speech privacy when the S/N ratio was below -6 dBA, and less than 20% of subjects reported high speech privacy when the S/N ratio was below -3 dBA. In contrast with the percentage for high speech privacy, the percentage of highly annoyed people increased as the S/N ratio increased. Specifically, the percentages of highly annoyed people were similar (below 30%) between -15 dBA and -6 dBA, whereas the percentage of highly annoyed respondents was found to increase significantly when the S/N ratio was over -3 dBA. The percentage of subjects reporting high speech privacy and the percentage of subjects highly annoyed, respectively, in terms of background noise levels. The background noise level affects speech privacy and influences the noise annoyance, as shown in Figure 2. The percentages of highly annoyed subjects significantly increased more than 60% with background noise level greater than 63 dBA. It is shown that interior noise levels between 60 dBA and 63 dBA may be appropriate considering noise annoyance in a passenger car of a high-speed train.

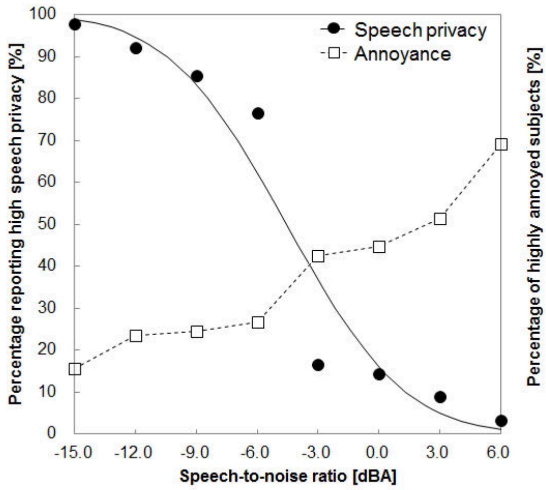

Figure 1. Percentage of subjects reporting high speech privacy and highly annoyed as functions of Speech-to-noise ratios.

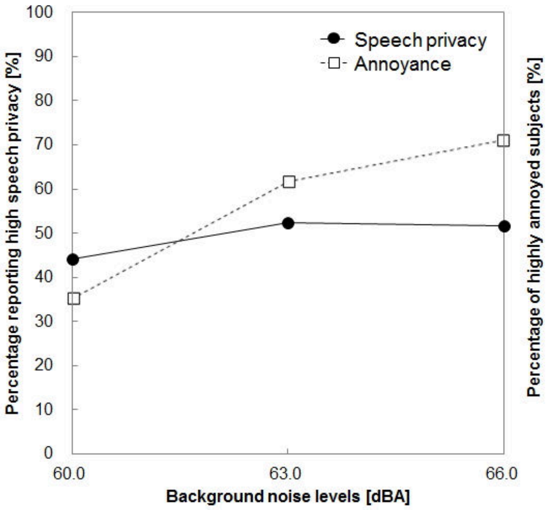

Figure 2. Percentage of subjects reporting high speech privacy and highly annoyed as functions of background noise levels

3. Conclusions

In this study, the effects of the interior noise levels in a high-speed train and the S/N ratio of speech to background noise on speech privacy, and noise annoyance were investigated using auditory experiments. It was found that the percentage of respondents who reported that speech privacy was good significantly decreased when the SNR increased over -3 dBA. In particular, the percentage of highly annoyed respondents considerably increased by approximately 20–30% when the interior noise was greater than 63 dBA. According to the results for speech privacy and noise annoyance, the optimal S/N ratio may be -6 dBA.

Speech effort is approximately 60 dBA. Thus, it can be suggested that the optimal range of background noise levels in a passenger car taking both speech privacy and noise annoyance into account is from 60 to 63 dBA.

Acknowledgement

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References

[1] A. E. J. Hardy: Measurement and Assessment of Noise Within Passenger Trains. Jounal of Sound Vibration **231** (2000) 819–829.

[2] J. Y. Jeon, H. S. Jang, J. Y. Hong: Evaluation of Speech Privacy in Passenger Cars of High-Speed Trains Based on Room Acoustic Parameters. Acta Acustica united with Acustica **89** (2014) 649–658.