Psychoacoustic experiments on feasible sound levels of possible warning signals for quiet vehicles

Daniel Menzel, Katsuya Yamauchi*, Florian Völk, Hugo Fastl

AG Technische Akustik, MMK, TU München, 80333 München, Germany, E-Mail: menzel@mmk.ei.tum.de
**on leave from: Department of Computer and Information Sciences, Nagasaki University, Japan*

Introduction

Vehicles with electric or hybrid engines have the advantages of being more environmentally friendly and quieter than internal combustion engines. However, reduced engine noise can also lead to potentially dangerous situations for pedestrians when an oncoming vehicle is inaudible in a given background noise (e.g. Kerber and Fastl [1]). One possible solution to this problem is the use of warning sounds which are radiated by the vehicle to alert pedestrians. A pilot study on this topic has been performed in Japan (Yamauchi et al. [2]), where the level of three possible warning sounds was adjusted in four different urban background sounds in a laboratory environment. For the present experiments, the input device and the layout of the test procedure were improved. In one experiment, subjects were asked to adjust the level of the warning sounds so that they are clearly audible and can be reliably detected in the background noise. In a second experiment the goal was to adjust the level so that the warning sounds are just audible. Results of the adjustments are presented and discussed in view of intra-individual and inter-individual differences. Moreover, they are compared to current recommendations for sound levels of warning signals in quiet vehicles.

Experiments

Stimuli

Four environmental background sounds were recorded in Fukuoka, Japan: a two-lane busy street in down town, a two-lane road in a residential area, six-lane heavy traffic and a narrow road in a shopping area. The recordings were performed binaurally using a head and torso simulator (HATS, Bruel & Kjaer, type 4100, free-field equalization) located on the sidewalk 1.5m above the ground.

Three potential warning sounds were used in this study: a car horn (sampled from a commercial CD), the sound of an idling gasoline engine (recorded at a distance of 2m to the vehicle), and bursts of band filtered white noise (1 to 10kHz). These sounds were played back over a loudspeaker in an anechoic room and re-recorded binaurally via the HATS to simulate a position 2m diagonally behind the subject.

Set-up and procedure

The experiments were performed in a darkened soundproof booth. The set-up is shown in Fig. 1: the signals were presented dichotically over Sennheiser HD-650 headphones. The input voltage to the headphones was measured, so that, knowing the headphone sensitivity, the playback level could be calibrated.

Subjects could adjust the level of the warning sounds using a slider visible on a computer screen (Fig. 1). The sound presentation was repeated until a button was pressed by the subjects indicating a satisfactory level adjustment. There were two tasks in each experimental session: one task was to adjust the warning sounds so that they are clearly audible and can be safely recognized in the different background sounds even without concentrating. The other task (performed for two of the four background sounds) was to adjust the warning sounds so that they are just audible. The order of these tasks was switched for each new subject. All stimulus combinations were presented once in pseudo-random order. All subjects took part in a second trial some weeks later to check for intra-individual differences.

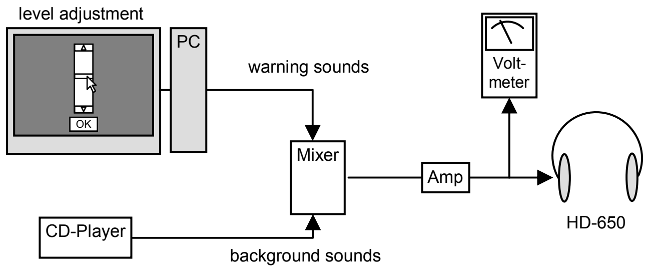

Fig. 1: Experimental set-up

Eleven male and four female German subjects aged 26 to 49 (mean 31.3) participated in the experiments. All reported normal hearing.

Results

Fig. 2 shows the inter-individual medians and interquartile ranges of the adjusted levels for all stimulus combinations. White symbols indicate warning signals which were adjusted to be clearly audible, black symbols show warning signals which were just audible. Additionally, the A-weighted RMS levels of the background sounds are marked by horizontal lines.

As expected, the adjusted levels of the warning signals depend strongly on the level of the background sounds. Differences between adjusted levels for each background sound correspond to the respective differences between the environmental sound levels. It can also be seen that the type of warning sound plays an important role. In each case, a car horn needed more level to be (clearly) audible than the other sounds, while band limited noise was detectable more easily. The levels of clearly audible warning signals are about 15 to 20dB higher than their respective audibility thresholds.

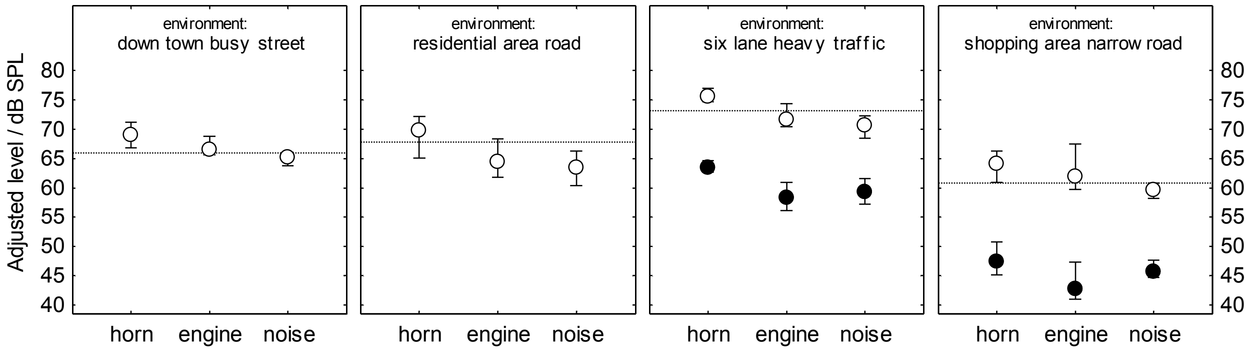

Fig. 2: Inter-individual medians and interquartile ranges of adjusted levels. White symbols: warning sounds clearly audible. Black symbols: warning sounds just audible. Horizontal lines: A-weighted level of environmental background sound.

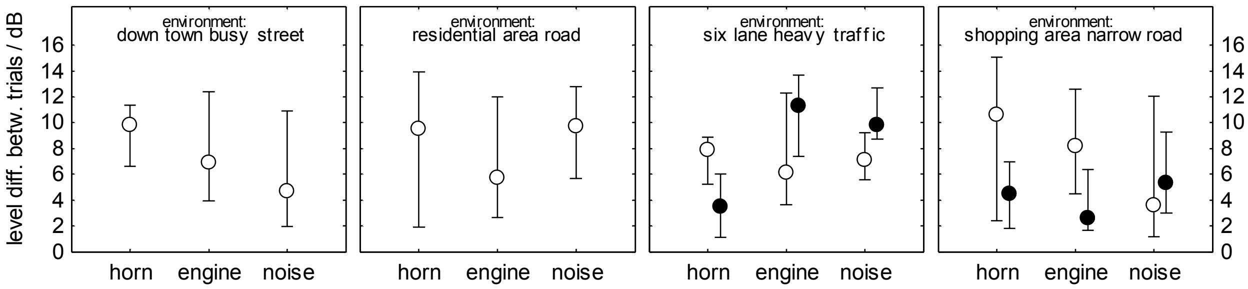

Fig. 3: Inter-individual medians and interquartile ranges of intra-individual level differences between trials. White symbols: warning sounds clearly audible. Black symbols: warning sounds just audible.

Inter-individual interquartile ranges can reach almost 10dB. This rather large variability is likely caused by the strong level fluctuations of the environmental background sounds (e.g. varying amount of cars passing by on the road). These fluctuations are probably also the reason for large intra-individual differences between the two trials (Fig. 3). Subjects frequently adjusted the same sound in the second trial to a level 10dB or more different from the first trial.

Discussion

The results shown in Fig. 2 indicate a strong influence of the type of warning sound as well as the background sound on the necessary level of the potential warning signal. A sound with an adequate level which is clearly audible in one environment (e.g. car horn in a shopping area), may be at the detectability threshold in another background (e.g. car horn in heavy traffic).

Regarding guidelines for sound levels of warning signals radiated by vehicles, it can be seen that recommending one fixed level could be problematic. For example, the Japanese guideline recommends a value of 50dB (Kamata [3]). Such a sound might be adequate in one particular environment, but might become inaudible and therefore ineffective in the presence of higher background levels. An adaptive strategy to adjust the radiated level to the current background sound might provide a more effective solution.

Acknowledgements

This study was partially supported by Japan Society for the Promotion of Science (JSPS), Grant-in-Aid for Young Scientists (A) 22680019, and Sound Technology Promotion Foundation.

References

[1] Kerber, S., H. Fastl: Perceptibility of approaching vehicles in urban background noise. In: Proc. inter-noise 2007, Istanbul, CD-ROM (2007)

[2] Yamauchi, K., M. Takada, K. Nagahata, S. Iwamiya: An Examination On Required Sound Levels For The External Acoustic Sign For "Quiet Vehicles". In: Proc. inter-noise 2010, Lisbon, CD-ROM (2010)

[3] Kamata, M.: Actions against the quietness of hybrid or such kind of quiet vehicles. In: Proc. Symposium on Sound Sign by Japanese Association for an Inclusive Society, Tokyo, pp.3-6 (2010)