Title	方向性の手掛かりが雑音環境下での報知音の検知能力に及ぼす影響
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Effects from spatial cues on detectability of alarm signals in noisy environments

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Alarm signals are sounds to provide informative notice to users. These signals are used for many purposes. It is important to detect them correctly in many sceneries. There are, however, cases where alarm signals cannot be correctly perceived in real environments due to noises. In car environments, for example, alarm signals are possibly masked by noises, and resulting in potential critical accidents in some cases. Therefore, methods for presenting alarm signals to be perceived accurately for drivers must be demanded. For this purpose, we must obtain fundamental data about perception of alarm signals in real environments, in particular, car environments.

In free sound fields, detectability of signals was improved when the signal and the masker were spatially separated. This phenomenon is referred as to spatial release from masking (SRM). For the occurrence of SRM, interaural time difference (ITD) and interaural level difference (ILD) are regarded as the significant spatial cues. On the other hand, according to varying the frequency components of signals, binaural masked level difference (BMLD) occurs at the same time. For the occurrence of BMLD interaural phase difference (IPD) is regarded as the significant spatial cue. It has been confirmed to use both ITD and IPD as the spatial cues for perception of alarm signals in car noise. The effectiveness of ILD has not yet considered in these conditions, although ILD has been known as one of the significant spatial cues for signal detection in free sound fields.

In this study, listening experiments were conducted to clarify effectiveness of the spatial cues for perception of alarm signals in noisy environments, in particular, car environments. The experiments were carried out in the virtual anechoic environments by using head-related transfer functions (HRTFs), which can be simulated presentation of loud speakers in an anechoic room. As advantages of using HRTFs, it is possible to extract ITD, IPD, and ILD and easily control presentation directions of signals. Here, we must note individuality of HRTFs when listening experiments are carried out in virtual acoustic environments regenerated by using HRTF. Therefore, at first, individualization of HRTF is carried out, and secondly, the listening experiments for the perception of signals in the presence of noise are carried out.

At the beginning, we found the individualized HRTF for each listener using a determination method of optimum impulse-response by sound orientation (DOMISO), which based on subjective evaluations by listeners. Moreover, in order to evaluate whether the HRTF selected by each listener is suitable. Evaluation criteria were set the correct rate of localization and the front-back confusion error rate. Only the listeners who satisfied the evaluation criteria participated in the listening experiments.

In this study, the purpose of listening experiments is to clarify how spatial cues effect perception of alarm signals in noisy environments. Therefore, as a first step, in order to confirm whether the acoustic environment regenerated by using individualized HRTF can simulate the presentation using loud speakers in an anechoic chamber, we carried out the listening experiments under same condition as that of the previous study (Experiment I). As a second step, we carried out the listening experiments for perception of alarm signals in car noise environment (Experiment Ⅱ). Finally, we carried out the listening experiments for perception of alarm signals in car noise environment using two maskers (Experiment Ⅲ).

In Experiment I, the target signal and masker were a pulse train signal and white noise. In Experiment Ⅱ, the target signal and the masker were alarm signals and car noise. Frequency components of the alarm signals were 1.0 and 2.5 kHz. In the Experiment Ⅲ, the target signal and the masker were used the same signals as Experiment Ⅱ, and two maskers were set. The car noises were recorded in a car interior with the window open while the car was traveling at 60 km/h. The sampling frequency was 48 kHz. Presentation directions of the stimuli were varied from 0° to 90° at the step of 15°, the direction in front of the listeners was 0°. In the listening experiments, the masked thresholds of the target signals by the masker were measured by using the method of limits. Here, the sound pressure level of the masker was fixed to 65 dB at the beginning of the experiments. All of the experiments were carried out in a sound-proof room. Six graduate students who had normal hearing were participated for the experiments.

As the results of Experiment I, Experiment Ⅱ and Experiment Ⅲ, we clarified the followings.

- For the perception of the pulse train signal under white noise, when the masker was fixed in the front of the listeners, ITD greatly effected SRM. Meanwhile, when the target signal was fixed in the front of the listeners, ITD and ILD greatly effected SRM.

- For the perception of the alarm signal under car noise, when the frequency component of the alarm signal was 1.0 kHz, ITD and IPD greatly effected the detectability of the alarm signals.

- For the perception of the alarm signal under car noise, when the frequency component of the alarm signal was 2.5 kHz, ITD and IPD greatly effected the detectability of the alarm signals in the condition that the masker was fixed in the front of the listeners. Meanwhile, when the target signal was fixed in the front of the listeners, ITD, IPD, and ILD greatly effected the detectability of the alarm signals.

- For the perception of the alarm signal in the presence of two maskers, when the frequency component of the alarm signal was 2.5 kHz, ITD and IPD greatly effected the detectability of the alarm signals.