



**Acoustics'08
Paris**
June 29-July 4, 2008

www.acoustics08-paris.org

euronoise

Subjective experiment on auditory localization for traffic alarm sounds

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When riding a motorbike with a helmet or driving a car, it is often experienced that the judgment of directions of alarm sounds like a horn and sirens of engine truck and ambulance car becomes difficult. This kind of auditory localization is seriously related to traffic safety. In this study, therefore, the effects of covering the driver's head with a helmet and sound transmission into a car on the auditory localization for traffic alarm sounds were examined by laboratory tests. To simulate a 3-dimensional sound field, the 6-channel recording/reproduction technique was applied and the incident direction of the test sounds was varied in twelve horizontal directions.

1 Introduction

When riding a motorcycle, wearing a crash helmet is effective to defend the rider from serious accident, but it might influence the rider's ability of sound source localization for alarm sounds and running noises of other vehicles [1]. In a similar way, it is often experienced that the direction of such sounds as horn sounds and sirens of engine truck and ambulance car becomes difficult to judge inside a car. In this paper, therefore, these acoustic problems are discussed by performing psycho-acoustical experiments using a 3-dimensional sound field reproduction technique.

2 Experimental system

2.1 6-channel recording/reproduction system

Figure 1 shows the block-diagram of the 6-channel recording/reproduction system [2-3] used in this study. In this system, the receiving system consisting of six uni-directional microphones combined at every 90 degrees in the horizontal and vertical plane is used. The respective 6-channel signals recorded through this system are reproduced through six loudspeakers set in an anechoic room, which are arranged at every 90 degrees in the same way as for the microphone set (see Fig.2).

2.2 Accuracy of reproducibility

By using this system, not only sound pressure but also particle velocity is accurately reproduced in the center point of the reproduced sound field and therefore the sound intensity vector can be reproduced at the point. When hearing the sounds at the center point, a natural impression can be obtained with 3-dimensional information.

To examine the reproduction accuracy of the 6-channel system from psycho-acoustical viewpoint, the auditory localization tests have been performed. For these studies, impulse responses at every 30 degrees around the receiving system in the horizontal plane were measured in an anechoic room using the swept-sine method. In this measurement, a loudspeaker sound source was located at a point 7 m from the receiving system. The measured 6-channel directional impulse responses were convolved with a pink noise burst (on-time:1 s, off-time:0.5 s) and they



Fig.2 Reproduction system set in a semi-anechoic room.

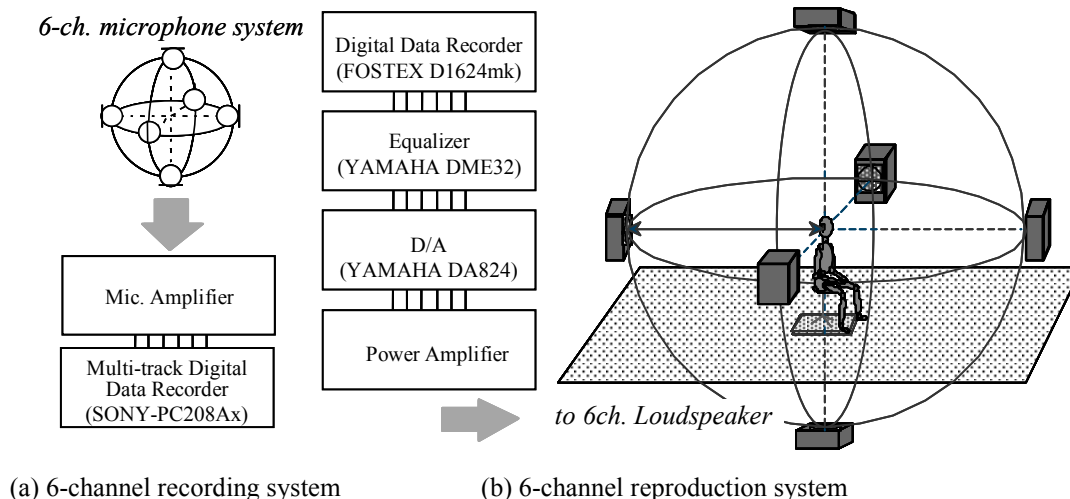


Fig. 1 Diagram of 6-channel recording/reproduction system.

were reproduced from the six loudspeakers set in the anechoic room in random order. The judgment test on the direction of the sound source was performed under two experimental conditions: one was that the subject sitting at the center position of the reproduced sound field by keeping his/her head fixed to the front direction and the other was that the subject was allowed to turn his/her head when judging the direction. Ten university and graduate students with normal hearing ability participated in this experiment. The judgment results by all of the subjects are shown in Fig. 3, in which the diameter of each circle indicates the relative number of the response. In these results, it can be seen that the direction of the sound source was judged with a considerably high accuracy in both experimental conditions.

3 The effect of wearing a crash helmet

In order to examine the effect of wearing a crash helmet, auditory localization test was performed under two conditions with/without a helmet (see Fig. 4). For these experiments, a horn alarm of a passenger-car was recorded through a monaural microphone and it was convolved with each of the six directional impulse responses mentioned above. As the test condition, the direction of the sound

source was set at every 30 degrees in a horizontal plane. In this test, ten university and graduate students with normal hearing ability participated. The experimental results judged by all of the subjects are shown in Fig. 5. In the results under the condition without a helmet, it is indicated that the direction of sound source is detected with high-accuracy. On the other hand, under the condition with a full-face type helmet, it is seen that oblique back and forth directions are frequently mistaken, although judgments of right and left side are not mistaken. From these results, the influence of covering his/her head with a crash helmet can not be disregarded from an acoustical point of view.

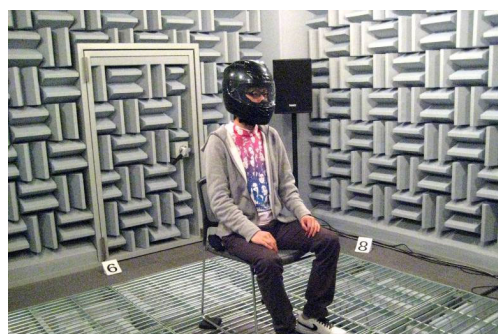
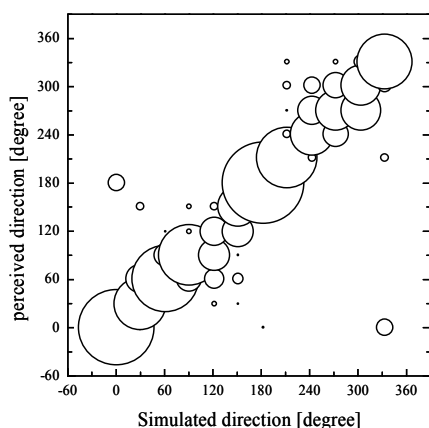
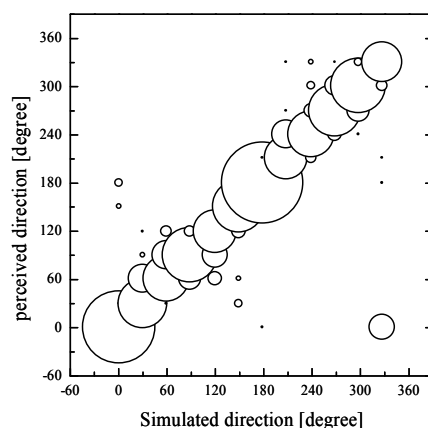


Fig. 4 Localization test under the condition with a full-face type helmet.

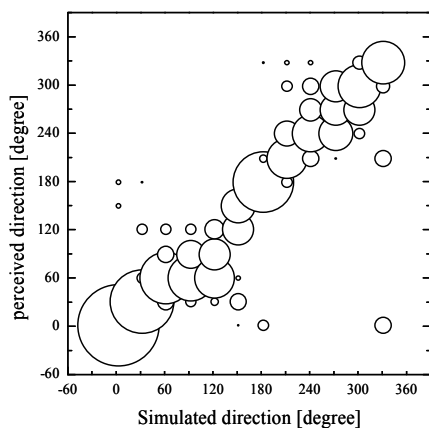


(a) keeping the subject's head fixed to the front direction

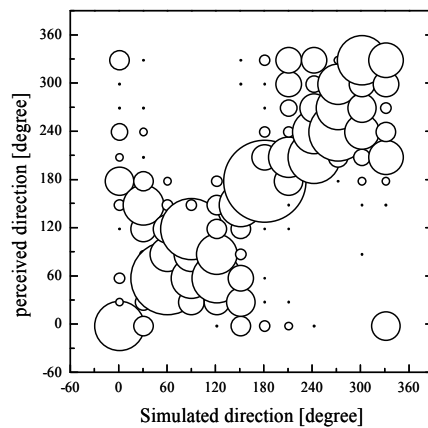


(b) allowed to turn the subject's head

Fig. 3 Experimental results of localization tests using the pink noise burst.



(a) judgment under the condition without a helmet



(b) judgment under the condition with a helmet

Fig. 5 Experimental results of localization tests using an alarm sound.

4 Direction judgment of alarm sounds inside a car

4.1 Measurement of the transmission characteristics from outside to inside of a car

To simulate the situation of listening to the alarm sounds transmitted into a car, the directional impulse responses from outside to inside of a passenger car were measured. As shown in Fig.6, a swept-sine signal was generated from a dodecahedral loudspeaker set outside the car and the 6-channel microphone system was located at the driver's seat. In this measurement, the sound source was located at seven points at every 30 degrees only on the right-hand side of a half-circle around the center point of the driver's seat, and the impulse response data for the left-hand side were simulated by replacing the data for right-hand side.

4.2 Localization tests

As the test sound, the horn sound used in the previous experiment was again used in this study, and it was convolved with the directional impulse responses

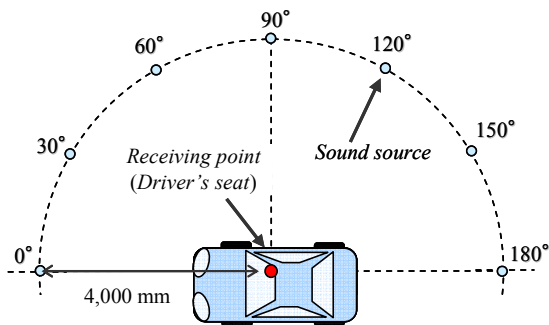
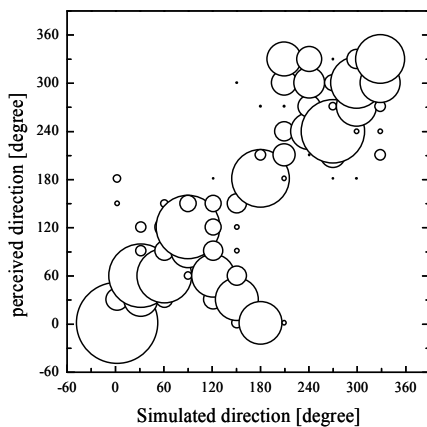
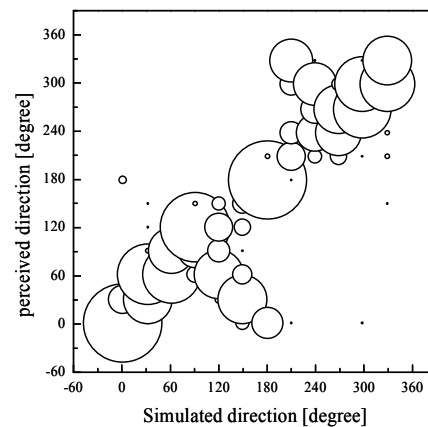


Fig. 6 Measurement of impulse responses from outside to inside of a car.



(a) keeping the subject's head fixed to the front direction



(b) allowed to turn the subject's head

Fig. 7 Experimental results of localization tests using an alarm sound transmitted inside a car.

mentioned above. The direction judgment test was performed in the same way as in the previous experiment under the two test conditions: one was that the subject's head was fixed facing to the front and the other was that the subject was allowed to turn his/her head freely when judging the direction of the test sound. Nine university and graduate students with normal hearing ability participated in this experiment.

The experimental results by all of the subjects are shown in Fig. 7. In these results, it is seen that the judgment of right/left sides is correct, whereas the sound from backward directions are apt to be misjudged to be forward directions.

5 Conclusions

In this study, the effect of wearing a crash helmet when riding a motorcycle and the sound shielding effect of a passenger car on the auditory localization ability of the driver was examined through psycho-acoustical experiments using the 6-channel recording/reproduction technique. As a result, it has been observed that the auditory localization ability is deteriorated under such riding/driving conditions. This fact should be further examined from a view point of driving safety and the improvement techniques should be investigated from an acoustical view point.

References

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