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INDIVIDUAL DIFFERENCES IN DIRECTIONAL BANDS

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ABSTRACT

Blauert and other researchers demonstrated that the sound image for a narrow-band noise is localized according to the center frequency of the stimuli. Blauert referred to the frequency band by which the direction of sound image is determined as the directional band. However, it has not yet been clarified if individual differences exist in the directional bands. It is also unestablished whether the directional band changes according to the bandwidth of the stimuli. In this study, 1/3 and 1/6 octave band noises were presented from the front, above and behind the subject in the median plane, and the responses to the stimuli were analyzed individually. The results show that (1) individual differences in directional bands exist; (2) there is no distinct difference between directional bands for 1/3 and 1/6 octave band noises; (3) for some subjects, a directional band occurs in the direction in which they could not localize wide-band noise.
KEYWORDS: Directional band, Sound localization, Individual difference

INTRODUCTION

Blauert [1] demonstrated that the direction of a sound image for a 1/3 octave band noise is a function of the center frequency only and does not depend on the source elevation angle. He referred to the frequency band by which the direction of sound image is determined as the directional band. Morimoto and Aokata [2] clarified that the same directional bands observed on the median plane occur in any sagittal plane. Middlebrooks [3] obtained a similar result; he showed that the angle around the interaural axis of subjects' responses tended to cluster within restricted spatial ranges that were specific to each center frequency.

However, a question arises regarding the directional bands of the studies mentioned above, which concerns the individual differences of directional band. Blauert [1] conducted an additional experiment in which he examined the individual variations of directional bands, and reported that "… the limits of the directional bands of the individual observers underlie inter-individual variations; however, in the center parts of the directional bands, inter-individual agreement is quite good." Middlebrooks [3] showed the existence of individual differences in the perceived angle around the interaural axis for each 1/6 band noise, which can be related to the subjects' own HRTF. It has not yet been clarified, from those results, if individual differences exist in the directional bands.

In this study, two localization tests were performed in order to clarify this point. In localization test I, wide-band noise was presented in the median plane; this test was performed in order to evaluate the accuracy of median plane localization of each subject. In localization test II, 1/3 or 1/6 octave band noise was presented in the median plane. The experimental results were analyzed individually, and discussed from the viewpoint of individual difference.

LOCALIZATION TEST I

Experimental Method. Subjects were six males and one female, aged from 26 to 42 years, with normal hearing sensitivity. With the exception of Subject E, all were experienced in this type of localization test.

The localization test was conducted in an anechoic chamber. Seven cylindrical loudspeakers were located every 30 degrees in the upper median plane, from the front (0 degrees) to the rear (180 degrees). The loudspeaker radius was 1.5 m relative to the center of the subject's head. The frequency characteristics of the seven loudspeakers were flattened to within ±2.0 dB in the frequency range of the stimulus using a frequency equalizer (Technics SH-8065). A laptop PC (Panasonic CF-R3) was supplied to the subjects to input their response.

The source signal was wide-band white noise ranging from 280 Hz to 11.2 kHz. The signal was presented from one of seven loudspeakers in the median plane. The stimuli were delivered at 60 dB(A) for 1.2 second, including 0.1 second onset and offset ramps, followed by an interval of 4.8 seconds.

Each subject was tested individually while seated, with the head fixed in a stationary position, in a darkened anechoic chamber. The subject's task was to plot the perceived elevation on the circle on the computer display, by clicking the mouse, during the interval of 4.8 seconds.

Experimental Results and Discussion. Figure 1 shows examples of the responses to the wide-band noise stimuli. The diameter of each circle plotted is proportional to the number of responses within five degrees. The ordinate of each panel is the perceived direction, and the abscissa is the target direction.

For subject D, the responses are distributed along a diagonal line; in other words, perceived elevation closely agreed with the target ones. On the other hand, for subject E, the sound images are localized in the rear for all target directions.

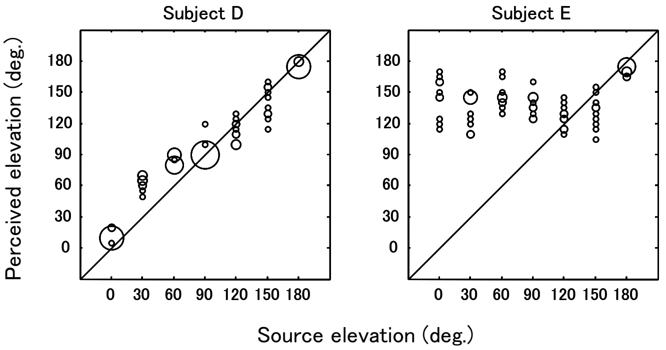

Figure 1. Examples of the responses to the wide-band noise stimuli.

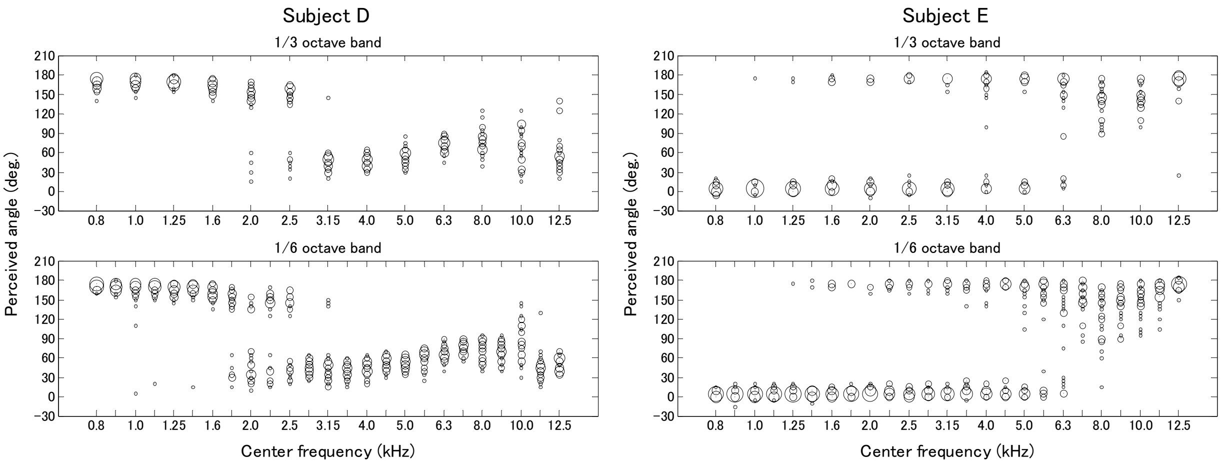

Figure 2. Examples of the responses to the narrow-band noise stimuli.

LOCALIZATION TEST II

Experimental Method. The source signals were 1/3 and 1/6 octave band noises. The center frequency of each narrow-band noise was in the range from 800 Hz to 12.5 kHz, in 1/3 and 1/6 octave steps, respectively. The signal was presented from one of three loudspeakers located in front (0 degrees), above (90 degrees) and behind (180 degrees) the subject.

The number of 1/3 and 1/6 octave band noise stimuli was 39 (13 center frequencies × three directions) and 75 (25 center frequencies × three directions), respectively. The other experimental conditions were the same as for localization test I.

Distribution of Responses. Figure 2 shows examples of the responses to the narrow-band noise stimuli. The area of each circle plotted is proportional to the number of responses within five degrees. The ordinate of each panel is the perceived direction, and the abscissa is the center frequency of the stimuli. For each panel, the upper and the lower row are the responses to the 1/3 and 1/6 octave noise stimuli, respectively. Note that all responses to the stimuli presented from three loudspeakers are summed in the figures.

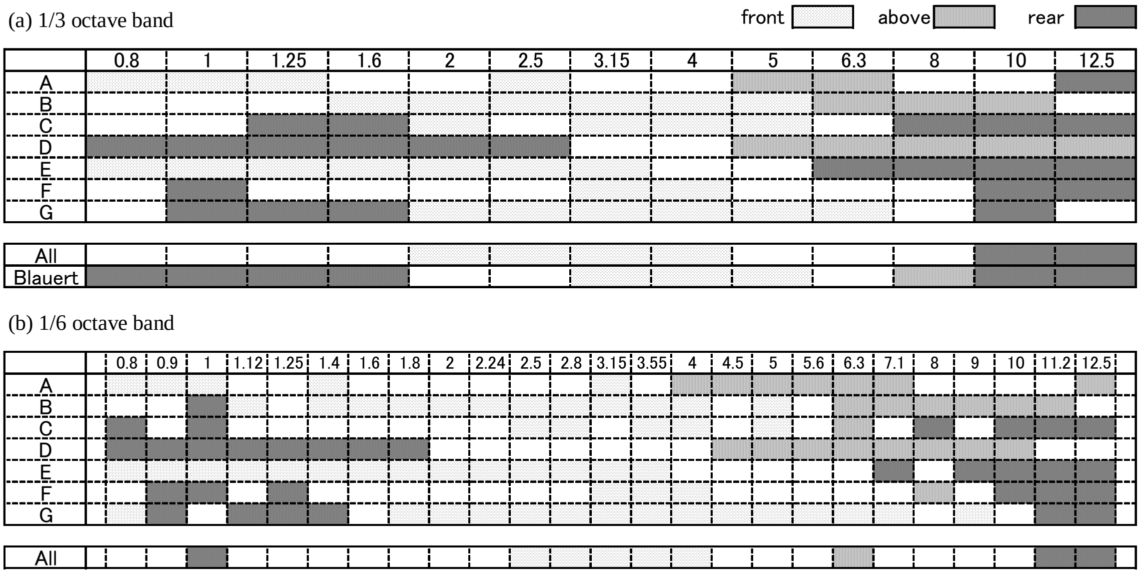

Figure 3. Directional bands derived after the method of Blauert [1].

Regarding the 1/3 octave band noise stimuli (upper row of each panel), subjects E and D mostly responded to the rear and in front, respectively, for the center frequencies of approximately 0.8-2.0 kHz. In other words, different directional bands occurred for these subjects. For the center frequencies of approximately 2.5-6.3 kHz, the responses of subject D shift from the front to above as the center frequency becomes higher. On the other hand, for subject E, the responses were separated into the front and rear. For the center frequencies of approximately 8.0-12.5 kHz, the responses of subject D were distributed around the front and above, and for subject E, above and behind.

Upon comparing the responses to 1/6 octave band stimuli (lower row of each panel) with those to 1/3 octave band stimuli, no distinct differences were observed, although the responses were somewhat scattered for 1/6 octave band stimuli.

Further inspection revealed that the responses of subject E were mostly concentrated in front for center frequencies of 0.8-1.25 kHz, although the subject localized sound images to the rear for wide-band noise stimuli presented from the front. In other words, a directional band occurred in the direction in which the subject could not localize the wide-band noise. Also, for center frequencies of 1.6-6.3 kHz, some responses were distributed around the front.

These results can be summarized as follows: (1) individual differences in directional bands exist; (2) for some subjects, directional bands occurred in the direction in which they could not localize the wide-band noise; (3) there was no distinct difference between responses to the 1/3 and 1/6 octave band noise stimuli.

Analysis of Directional Bands after Blauert. Next, directional bands were statistically derived, after the method of Blauert [1], as follows. (1) Each subject's responses were classified into three categories, that is, front ($\phi \leq 45$), above ($45 < \phi \leq 135$), and behind ($135 < \phi$), where is the elevation. (2) A frequency band is determined as the directional band if the number of responses in one category is significantly ($p<0.05$) larger than the sum of the others. The statistical method used for the test was the binominal test.

Figure 3 shows the results of statistical tests for each subject. The directional bands derived by summing the results for all subjects (‘All’ in Fig. 3), and the ones derived by Blauert [1] (‘Blauert’ in Fig. 3), are also shown in the lower row in each panel.

The comparison of the results for all subjects for 1/3 and 1/6 octave band noise with the results of Blauert indicates that fewer frequency bands were determined as directional bands in this study. Nevertheless, the same tendency is observed in both sets of results, that is, the directional bands occur to the rear for the center frequencies of 0.8-1.6 kHz, to the front for the center frequencies of 2-5 kHz, above for the center frequencies of 6.3-8 kHz, and again to the rear for the center frequencies of 10-12.5 kHz.

On the other hand, the directional bands of each subject have different tendencies, and there is no directional bands common for all subject. Therefore, it is regarded that individual differences in directional bands exist.

Upon comparing the directional bands for 1/3 octave band noise with the ones for 1/6 octave band noise, different directional bands are not apparent between the two types of band noise, with the exception of 12.5 kHz for subject A. Therefore, it can be regarded that no distinct difference exists between directional bands of 1/3 and 1/6 octave band.

Furthermore, frontal directional bands occurred for subject C for center frequencies of 0.8-3.55 kHz, respectively; in other words, a directional band occurs in the direction in which the subject cannot localize the wide-band noise, as mentioned above.

CONCLUSIONS

Localization tests were performed in order to examine the individual difference and the effect of the stimulus bandwidth in directional bands. In these tests, 1/3 and 1/6 octave band noises were presented in the median plane. The results indicate that (1) individual differences in directional bands exist; (2) there is no distinct difference between directional bands for 1/3 and 1/6 octave band noises; (3) for some subjects, a directional band occurs in the direction in which they cannot localize a wide-band noise.

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