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Perception of azimuth angle of sound source located at high elevation angle: Effective distance of auditory guide signal

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Abstract

In Japan, auditory guide signals are commonly installed in public spaces to lead visually handicapped pedestrians to their destinations. The sound sources of the signals are usually installed at high places on walls. In other words, the sound sources have not only an azimuth angle but also an elevation angle when viewed from the users. In the present study, under the hypothesis that the horizontal localization error increases with increasing elevation angle of the sound source, a sound localization test allowing head movement was performed to clarify the upper limit of the elevation angle. The results of the test were consistent with the hypothesis and indicated that the upper limit of the elevation angle was 65° within the range of the signal used in the present study and the assumption that the correct discrimination of eight directions is sufficiently accurate in the application of auditory guide signals. Furthermore, the effective distance of auditory guide signals, that is, the closest distance that users can approach to the destination using the signals was studied on the basis of the results of the present study. As a result, it was found that the effective distance of auditory guide signals does not exceed 1 m, in other words, the signals work effectively in the range horizontally farther than 1 m, when the height of the sound source

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is less than 3 m.

Keywords: Sound localization, Head movement, Visually handicapped persons

1. Introduction

In Japan, auditory guide signals are commonly installed in public spaces to lead visually handicapped pedestrians to their destinations. The signal is radiated from a loudspeaker installed near destinations, and visually handicapped persons navigate with the help of the perceived direction of the signal. The sound sources of the signal are usually installed at high places on walls or on ceilings to decrease obstacles on the path to the users and to transmit the signal to as many users as possible. In other words, the sound sources have not only an azimuth angle but also an elevation angle when viewed from the users.

Usually, users can move their heads while listening to the signal and can listen to the signal as many times as they want. Previous studies[1–7] reported that head movement during sound localization produces dynamic cues, and utilization of the cues significantly decreases the front-back localization error. Therefore, if users are instructed to move their heads so that the sound image is localized somewhere in the front half of the median plane regardless of elevation angle, and to walk in the direction they are facing after moving their head, they can approach the destination. This means that the effectiveness of the signal does not depend on accuracy of the perceived elevation angle.

However, a too high elevation angle of the sound source can make it difficult to distinguish whether or not the sound image is localized in the median plane. Here, consider the perception of the difference between the perceived azimuth angle of the sound source and the median plane, premising the head movement. To simplify the discussion, the following are assumed.

(1) The minimum audible angle (MAA) in the lateral angle with reference to the median plane does not depend on the height of the sound source[8].

(2) The head movement of the listener is limited to *rotating*, which occurs most frequently[9].

In Fig. 1, φ_{thre} is the MAA in the lateral angle with reference to the median plane, φ_{rot} is the rotation angle of the listener's head with reference to the sound source direction, and θ is the elevation angle of the sound source. The listener cannot notice that sound sources located between the sagittal planes for lateral angles of $\pm\varphi_{\text{thre}}$ deviate from the median plane, because the absolute value of the lateral angle is smaller than φ_{thre}. When the sound source shown in Fig. 1 moves to a higher position on the circular arc indicated by a thick line, namely it moves maintaining the same azimuth angle of $-\varphi_{\text{rot}}$ and distance from the listener (r), the lateral angle of the sound source seen from the listener is smaller than φ_{thre}. In this case, the listener has to rotate own head more than φ_{rot} shown in Fig. 1 to notice that the sound source deviates from the median plane.

[Figure 1 about here.]

The relationship among $\varphi_{\text{rot,min}}$, which is the minimum rotation angle of the listener's head required for the listener to notice that the sound source deviates from the median plane, θ, and φ_{thre} is given by Eq. 1. $\varphi_{\text{rot,min}}$ can be regarded as the potential maximum of the localization error in azimuth. Assuming that φ_{thre} is constant, Eq. 1 implies that the expected value of the localization error in azimuth increases with increasing θ.

$$\varphi_{\text{rot,min}} = \arcsin\left(\frac{\sin\varphi_{\text{thre}}}{\cos\theta}\right). \tag{1}$$

The hypothesis in the present study is that the elevation angle of the sound source determines the accuracy of the azimuth localization of auditory guide signals. Considering the hypothesis from the viewpoint of the application of auditory guide signals, when the distance from the sound source becomes shorter than a certain value, the elevation angle exceeds the angle at which people cannot be guided correctly. This means that the elevation angle determines how close the user can approach the destination. Makous and Middlebrooks[10] reported that listeners could localize the horizontal direction of a loudspeaker if the elevation angle is up to 45°, but there has been no previous research on sound localization in the azimuth angle for sound sources with elevation angles more than 45°.

In the present study, a sound localization test allowing head movement was performed to clarify the upper limit of the elevation angle. In addition, based on the results, the effective distance of auditory guide signals, that is, the closest distance that users can approach to the destination using the signals in the case of a typical sound source position in real situations, was studied.

2. Experimental conditions

Seven university students participated in the experiment as listeners. None of the listeners had received specialized education on sound localization. No listeners declared a visual impairment. The results of an audiometry test using pure tones from 125 Hz to 8 kHz confirmed that all listeners had normal hearing ability.

A wide-band noise from 100 Hz to 20 kHz and a low-pass noise from 100 Hz to 500 Hz were used as acoustic signals. A white noise with a duration of 60 s was filtered through a band-pass filter (NF, 3625), with a frequency cutoff of −96 dB/oct to obtain the two noises. The frequency characteristics of the two noises were determined so that the wide-band noise could provide both interaural difference cues and spectral cues for sound localization while the low-pass noise could only provide the ITD cue. As described later, the acoustic signal was repeatedly presented without interruption until the listener confirmed the answer.

The experiment was carried out in an anechoic chamber. Four loudspeakers (Fujitsu-Ten, ECLIPSE TD307II) were located at elevation angles of 55°, 65°, 75°, and 80° on an arch of a circle of radius 1.5 m centered at the listener's head, as shown in Fig. 2. Figure 3 shows an example of the frequency characteristics of the four loudspeakers. Except for a steep dip around 18 kHz, the characteristics did not have dominant peaks or dips in the frequency range of the acoustic signals. The binaural sound pressure level[11] of the acoustic signals was 65 dB (L_{AFmax}), measured using a KEMAR dummy head facing the direction of $\varphi = 0$ and $\theta = 0$.

[Figure 2 about here.]

[Figure 3 about here.]

Each listener was seated on a swivel chair without a headrest or armrests. The listener's head was not fixed. The listener could freely change the horizontal direction of the head and the torso by rotating the chair. The chair was placed on a protractor with scale lines every 5°. The zero angle of the protractor was set to the azimuth angle of the loudspeakers. A laser pointer was mounted vertically downward on the front center of the back of the seat to measure the direction in which the listener was facing.

A total of 40 conditions (2 acoustic signals × 4 elevation angles × 5 initial azimuth angles) were tested. The initial azimuth angle (φ_{i}) is the direction that the listener faces at the start of the experiment. Five initial azimuth angles of 0°, 45°, 90°, 180°, and −135° were used (see Fig. 2).

The experimental procedure was as follows.

(1) The listener was blindfolded before entering the anechoic chamber, and remained blindfolded while in the chamber.

(2) The listener was guided by the experimenter to the chair, then sat down, with his/her lower back resting against the vertical part of the chair.

(3) The experimenter rotated the chair randomly to confuse the spatial mind map of the listener. After that, the experimenter set the direction of the listener to one of the five initial azimuth angles.

(4) One of the two acoustic signals was presented from one of the four loudspeakers.

(5) The listeners were instructed to perform the following two tasks: (a) to direct their face and body in the horizontal direction of the sound source by rotating the chair by themselves, (b) to push the button at hand when they had finished directing their face and body, (c) to maintain their posture at the beginning of the experiment as much as possible when rotating the chair.

(6) The acoustic signal was repeatedly presented without interruption until the listener pushed the botton.

(7) After the sound stopped, the experimenter read the scale line of the protractor under the chair that was closest to the light of the laser pointer.

Each condition was tested four times in random order for each listener. Therefore, each listener repeated the above procedure 160 times. The experiment for each listener was separated into 10 sessions with a break between them.

3. Results and discussion

[Figure 4 about here.]

Figures 4 (a)–(j) show bubble charts of the distribution of the azimuth localization error for each combination of the initial azimuth angle (φ_{i}) and the acoustic signal. The azimuth localization error is the difference in azimuth between the loudspeaker direction and the direction read in the procedure (7) described in the previous section. The azimuth localization error is a value in steps of 5 degrees. A positive value indicates an error to the right, and a negative value indicates an error to the left. The area of the circle in the figures is proportional to the number of the error. Since there were no qualitative individual differences in the trend of the results, the results of all the listeners were combined. Therefore, the number of samples for each condition was 28 (7 listeners $\times$ 4 trials).

3.1. Trends common to wide-band and low-pass noise

There are three common trends in the distributions of the wide-band noise and low-pass noise. Firstly, the maximum error was 70°, which is shown in Fig. 4(f) as a negative error. This means that no front-back error occurred in the experiment even for the low-pass noise, which did not contain spectral cues. This trend is consistent with the previous studies on sound localization with head movement[1–7].

Secondly, the effect of the initial azimuth angle was not systematic. This might have been due to the unlimited presentation time of the acoustic signal. The time from the start of presentation of the signal until the listener pushed the button was in the range of 5 s to 12 s. This range is sufficiently longer than the time required to utilize dynamic interaural cues caused by head movement (0.8 s–3 s)[4, 6, 7]. Table 1 shows the results of the Friedman test ($p < 0.05$) on the absolute value of the localization error. The results indicate that the error was significantly affected by the initial azimuth angle when the elevation angle was 55° and 65°. However, systematic effects such as the error greatly decreasing at a specific initial azimuth angle could not be found at these elevation angles.

Thirdly, relatively large localization errors occurred at the elevation angles of 75° and 80° rather than at 55° and 65°. The Friedman test ($p < 0.05$) on the absolute value of the localization error showed a significant effect of the elevation angle for nine out of ten cases (see Table 1). This trend supports the hypothesis in the present study that the elevation angle determines the accuracy of horizontal localization.

[Table 1 about here.]

3.2. Differences in average and variance

In the following, data combining all the initial azimuth angles for each elevation angle are analyzed because the effect of the initial azimuth angle was not systematic. The number of samples for the combined data was 140 (28 samples

$\times$ 5 initial azimuth angles). The Anderson–Darling test ($p < 0.05$) confirmed that all the combined data were normally distributed.

Table 2 shows the statistics of the localization error for each elevation angle and type of noise. The average error ranged from 2.3° to 7.3° for the low-pass noise, and from 1.4° to 4.0° for the wide-band noise. The averages indicate that the localization error had a positive bias, in other words, the sound source tended to be finally located to the left of the listener. This result might be related to the right-hemisphere dominance of the human brain for sound source lateralization[12, 13]; however, details are unknown. The bias was greater for the low-pass noise, but the data obtained in our previous study[7] using the same low-pass noise and the sound source located on the horizontal plane did not show such positive bias. This implies that a positive bias becomes apparent only under conditions where sound localization is difficult.

[Table 2 about here.]

Table 3 shows the results of an F-test ($p < 0.05$) on the equality of the two variances. A comparison between the same noises indicated that the variances for the elevation angle of 55° did not significantly differ from those for 65° while they increased when the elevation angle exceeded 75°, regardless of the type of noise. This result clearly confirmed that the variance of the localization error increased with increasing elevation angle and supported the hypothesis in the present study.

On the other hand, when comparing the two types of noise at the same elevation angle, the variance of the wide-band noise was significantly smaller than that of the low-pass noise for the elevation angles of 75° and 80°. One possible reason for this result is that φ_{thre} in Fig. 1 for the wide-band noise is smaller than that for the low-pass noise. Considering the MAA as a function of frequency measured by Mills[14] and the MAA as a function of the bandwith of the signal measured by Chandler and Grantham[15], φ_{thre} should decrease when acoustic signals contain mid-frequency components (around 600 Hz to 800 Hz), where the MAA is minimized. Another possibility is exact localization of the elevation angle using the spectrum cues included in the head-related transfer function (HRTF) that the wide band-noise provides. If the listener faces the sound source direction, that is, upwards, the elevation angle of the sound source relatively decreases. As a result, the localization error decreases. However, this effect is considered to be negligible because the listeners were instructed to maintain their posture as much as possible while listening to the stimulus and rotating the chair. In this case, good matching of the elevation angle perception using the spectrum cues and that using the dynamic cue suggested by Wallach[1] might have lowered the localization error.

[Table 3 about here.]

3.3. Acceptable accuracy and maximum elevation angle

The 95% prediction interval of the localization error is a practically important indicator in the application of auditory guide signal. The direction instruction of the mobility assistance device for the visually handicapped is often given in twelve directions according to the clock[16], or eight directions according to the compass[17]. Here, it is assumed that correctly distinguishing eight directions is a practically acceptable accuracy of azimuth localization. Under the assumption, the risk of misjudgment can be reduced to 5% or less when the 95% prediction interval is within the range of $\pm 22.5°$. Table 2 shows that the 95% prediction interval was within the range of $\pm 22.5°$ for the elevation angles of 55° and 65° regardless of the type of noise. Therefore, in the range of the present study, the maximum elevation angle to maintain acceptable accuracy of azimuth localization (θ_{max}) can be considered to be 65°. In other words, until the elevation angle of the sound source from the user of the auditory guide signals reaches 65°, the user will be able to judge the direction with an accuracy of eight directions and to approach the destination.

However, from Eq. 1, it is expected that θ_{max} will depend on φ_{thre} for the sound source and the acceptable accuracy of azimuth localization. Figure 5 shows $\varphi_{\mathrm{rot,min}}$ as a function of θ with the parameter of φ_{thre}. The curves in

Fig. 5 show the functions for $\varphi_{\rm thre}$ from 1° to 10° in 1° steps. As $\varphi_{\rm thre}$ increases, $\varphi_{\rm rot,min}$ for a certain θ increases. The acceptable localization accuracy can be thought of as a horizontal line in this figure, and it is possible to obtain $\theta_{\rm max}$ as the x-coordinate of the intersection of the horizontal line and the curve for the measured or expected $\varphi_{\rm thre}$.

[Figure 5 about here.]

In the following, to simplify the discussion, we ignore the positive bias of the localization error described in section 3.2. When $\varphi_{\rm thre}$ is set to a value considering the application of the auditory guide signals, that is, a value giving 5% probability of incorrect judgment, $\varphi_{\rm rot,min}$ corresponds to half the width of the 95% prediction interval of the localization error. The half widths of the 95% prediction interval of the localization error in the present study are overlaid in Fig. 5. If the localization error is determined according to the mechanism shown in Fig. 1, the data for each type of noise will be located on a certain curve.

Regarding the low-pass noise, the widths for θ from 65° to 80° were located close to the curve for $\varphi_{\rm thre}$ of 7° and 8°; however, that for θ of 55° was located at a higher position than for the other values of θ, i.e., on the curve for 10°. Regarding the wide-band noise, the widths for θ of 75° and 80° were located close to the curve for $\varphi_{\rm thre}$ of 6°; however, also here those for θ of 55° and 65° were located at higher positions than for the other values of θ. In our previous study[7], we conducted an experiment similar to the present study using a continuous low-pass noise (100 Hz–500 Hz) with a duration of 1600 ms that was presented from one of eight loudspeakers located on the horizontal plane (θ=0°). The 95% prediction interval of the localization error for the acoustic signal was ±15°. Considering that the width of the interval in the previous study and that for θ of 55° in the present study were not so different, it can be assumed that there is a lower limit of the width, which is determined by factors other than $\varphi_{\rm thre}$. It is considered that accuracy of motion control, that is, how precisely head or body can be oriented toward the sound source, is one such factor. The result that there were not significant differences among the variances of the localization error for the four combinations of θ of 55° and 65° and the two types of noise (see Table 3) does not contradict the existence of such factors.

In the range where $\varphi_{\mathrm{rot,min}}$ is clearly larger than 15°, the curves in Fig. 5 are considered to be an appropriate explanation of the experimental results. From Fig. 5, it can be assumed that φ_{thre} for the low-pass noise is 8°. In this case, if the acceptable localization accuracy is set to 22.5°, θ_{max} for the low-pass noise is read to be 68.7° from Fig. 5, which is roughly equal to θ_{max} of 65° suggested from Table 2.

3.4. Comparison with the 75% thresholds

The MAA in front of a listener measured by Mills[14] was almost constant at 1° in the frequency range from 250 Hz to 1 kHz. The MAA is clearly smaller than φ_{thre} discussed in the previous section. However, in real situations, a larger φ_{thre} will be necessary, considering the following points.

Firstly, the head movement can decrease the MAA. Previous studies commonly reported that the localization accuracy decreased when the sound source or the listener was moving[18]. There have only been a few studies[19, 20] on the measurement of such thresholds when the sound source is stationary while the listener's head is moving. Brimijoin and Akeroyd[19] reported that the minimum angular separation for speech signals in front of a listener with head movement was 4°.

Secondly, it is doubtful that people can precisely judge whether or not a sound image is located on the median plane without a reference signal, which is usually used in threshold measurements. Furthermore, in general, the MAA is measured as the difference at which a correct answer rate of 75% is obtained with regarding the presence or absence of a difference between the locations of stimuli.

For comparison with previous studies, φ_{thre} corresponding to the 75% thresholds was estimated from the results of the present study. Generally, the threshold is obtained by comparative judgment of the signal presented from the front direction and the signal presented from another direction. According to Case V of Thurstone's law of comparative judgment, if there is a difference of $\sqrt{2}\times 0.68$ times the standard deviation of the perceived direction of the sound image, it is possible to detect the difference with a correct answer rate of 75%. The 75% thresholds for each θ and type of noise obtained from the standard deviation shown in Table 2 are overlaid in Fig. 5. The 75% thresholds were near the curve for φ_{thre} of 3° or 4°. These values are equivalent to the 75% threshold for the condition that listeners move their head during sound localization reported by Brimijoin and Akeroyd[19], and this indicates that the results of the present study are reasonable.

3.5. Effective distance of auditory guide signals

In this section, the method of arranging the sound source on the basis of θ_{max} is discussed. The following relationship is obtained from Fig. 6:

$$h_1 = h_2 + d_{\mathrm{e}} \tan \theta_{\mathrm{max}}, \tag{2}$$

where h_1 is the height of the sound source, h_2 is the height of the user's ear, and d_{e} is the effective distance of the auditory guide signal, that is, the closest distance that users can approach to the destination using the signal. The effective range of the auditory guide signals begins at d_{e} and continues until background noise and reverberation sound spoil sound localization of the distance-decayed direct sound.

[Figure 6 about here.]

From the discussion in section 3.3, it is expected that a higher θ_{max} is acceptable in the case of wide-band noise, but here θ_{max} of 65° is conservatively adopted as a criterion. As shown by Mills[14], the MAA greatly increases at frequencies above 1 kHz, while there is only a small difference in the frequency range from 250 Hz to 1 kHz. Therefore, provided wide-band auditory guide signals including this frequency range are used, it is unlikely that θ_{max} will be lower than 65°.

h_2 in public spaces is assumed to range from 1.16 m to 1.75 m to include wheelchair users according to anthropometric data (eye level) published by the United Nations[21]. Therefore, the lower limit of h_2, which is critical for determining the upper limit of h_1, is considered to be about 1.0 m. When h_2 is 1.0 m and θ_{max} is 65°, h_1 calculated to be 2.1 m for d_{e} of 0.5 m and 3.1 m for d_{e} of 1.0 m. In ISO Standard 19029:2016 on auditory guide signals[22], the height of the sound source is set to 0.8 m or less or 2.4 m or more to avoid an excessive presentation level and physical contact between users and sound sources. On the other hand, in the same standard, although the reason is not clarified, a height of 3.0 m is recommended as the upper limit of the sound source height. The worst combination of h_1 and h_2 considered here is $h_1 = 3.00$ m and $h_2 = 1.16$ m. In this case, d_{e} is calculated to be 0.86 m for θ_{max} of 65°. According to the report by Brungart and Rabinowitz[23], when the sound source was in front, the interaual differences that determines φ_{thre} are hardly dependent on the distance until the listener approaches the sound source closer than 0.5 m. Therefore, it is considered that users can approach the destination to a horizontal distance of about 1 m at least, given a sound source is installed in accordance with this standard.

4. Conclusions

In this study, it was assumed that the localization error of the azimuth angle increases as the elevation angle of the sound source increases, and a sound localization test allowing head movement was performed.

Regarding the upper limit of the elevation angle of the sound source providing auditory guide signals, the following were clarified.

(1) The hypothesis of the present study that the horizontal localization error increases with increasing elevation angle of the sound source was demonstrated from the results of the localization test. However, the error did not become sufficiently large to cause front-back misjudgment.

(2) The relationship among the elevation angle of the sound source, the threshold of the lateral angle of the signal, and the minimum rotation angle of the listener's head required to notice that the sound source deviates from the median plane was formulated. The formulated relationship matched the results of the localization test reasonably well.

(3) Assuming that the correct discrimination of eight directions is sufficiently accurate in the application of auditory guide signals, the upper limit of the elevation angle was 65° within the range of the signal used in the present study.

Regarding the effective distance of auditory guide signals, that is, the closest distance that users can approach to the destination using the signals, the following was found when applying the upper limit of the elevation angle obtained in the present study.

(4) The effective distance of auditory guide signals does not exceed 1 m, in other words, the signals work effectively in the range horizontally farther than 1 m, when the height of the sound source is less than 3 m.

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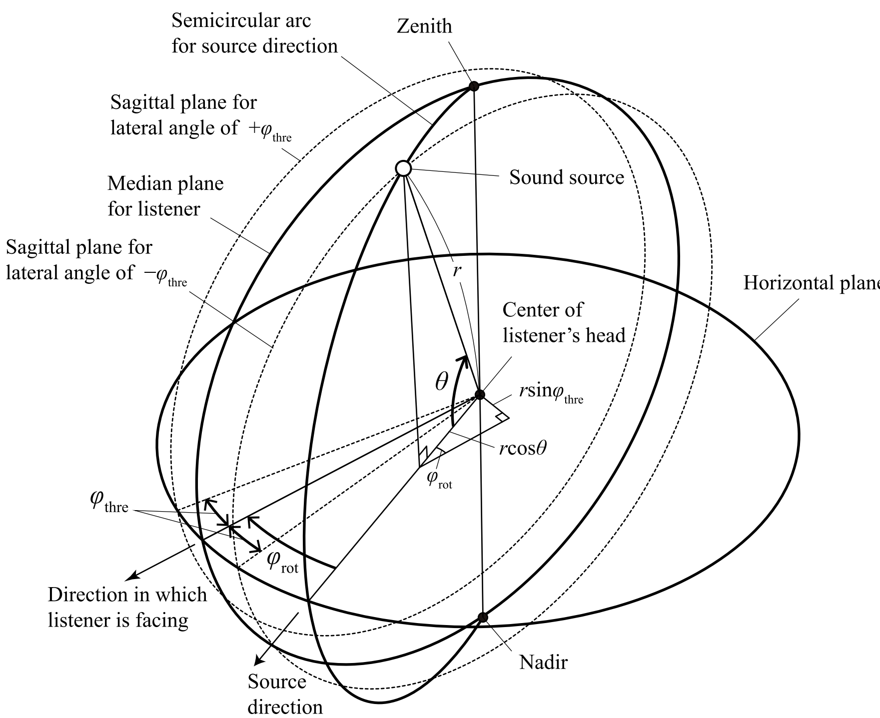

Figure 1: Geometrical relationship among the elevation angle of the sound source (θ), listener's rotation angle relative to the source direction (φ_{rot}), and the minimum audible lateral angle (φ_{thre}) relative to the direction in which the listener is facing. r represents the distance between the listener and the sound source.

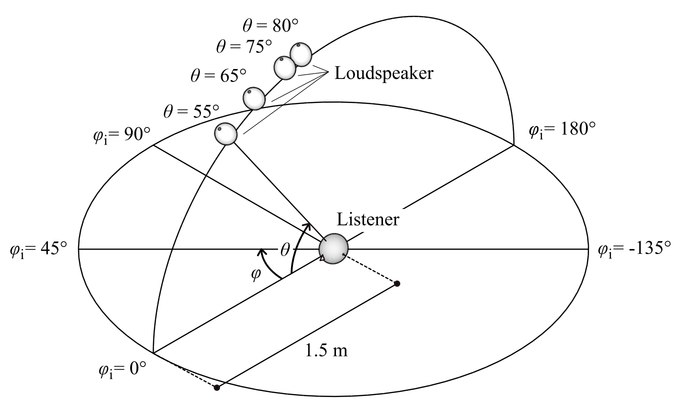

Figure 2: Arrangement of the loudspeakers used for the experiment. θ is the elevation angle of each loudspeaker. φ_{i} is the initial azimuth angle, that is, the direction that the listener faces at the start of the experiment.

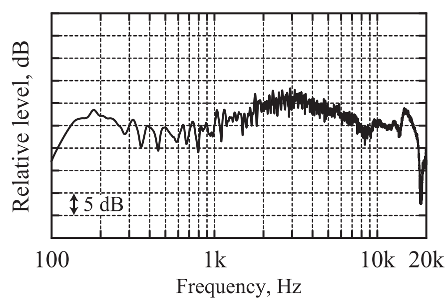

Figure 3: Example of the frequency characteristics of the loudspeakers used in the experiment.

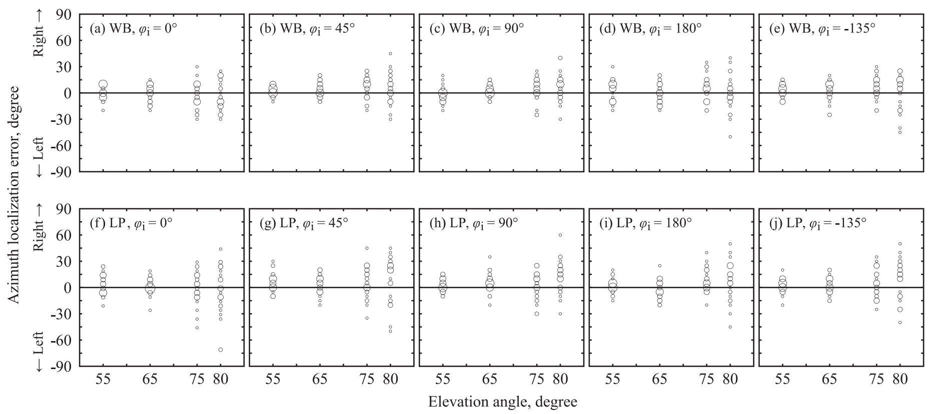

Figure 4: Distribution of the azimuth localization error for each condition. Panels (a)–(e) show the results for the wide-band noise (WB: 100 Hz–20 kHz) and panels (f)–(j) show those for the low-pass noise (LP: 100 Hz–500 Hz). φ_i is the initial azimuth angle (see Fig. 2). A positive value indicates an error to the right, and a negative value indicates an error to the left. The area of the circle is proportional to the number of the error.

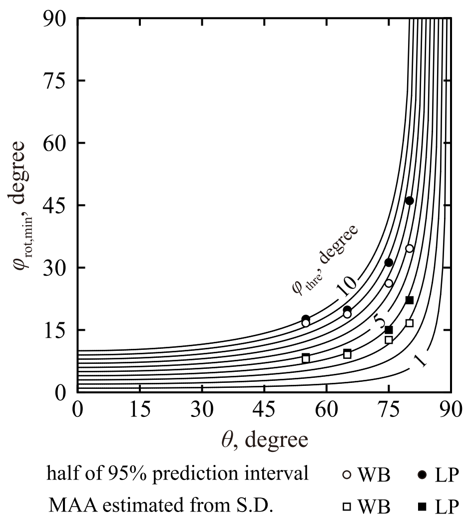

Figure 5: The minimum rotation angle of the listener's head required for the listener to notice that the sound source deviates from the median plan ($\varphi_{\mathrm{rot,min}}$) as a function of the elevation angle of the sound source (θ) with the parameter ofthe minimum audible lateral angle (φ_{thre}). Open (closed) circles and squares represent half of the 95% prediction interval and the 75% threshold estimated from the S.D. for the wide-band (low-pass) noise for each elevation angle, respectively.

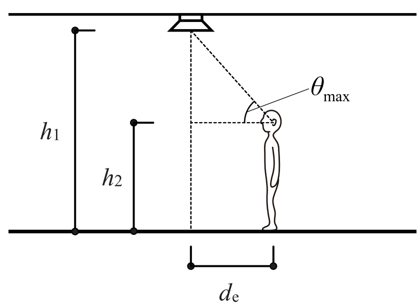

Figure 6: Definition of d_e.

List of Tables

Table 1: p-Values of the Friedman test ($*p < 0.05$) for effects of the initial azimuth angle and the elevation angle on the absolute value of the localization error.

Effect of initial azimuth angle			Effect of elevation angle		
Elev. angle	Low-pass	Wide band	Azim. angle	Low-pass	Wide band
55°	$1.74\times10^{-2}*$	$5.67\times10^{-3}*$	0°	$9.59\times10^{-5}*$	$1.45\times10^{-3}*$
65°	3.74×10^{-1}	$4.16\times10^{-2}*$	45°	$4.92\times10^{-5}*$	$2.49\times10^{-4}*$
75°	8.23×10^{-1}	8.50×10^{-1}	90°	$7.14\times10^{-4}*$	$7.78\times10^{-3}*$
80°	2.65×10^{-1}	3.36×10^{-1}	180°	$7.76\times10^{-5}*$	9.10×10^{-1}
			−135°	$1.16\times10^{-8}*$	$1.46\times10^{-3}*$

Table 2: Statistics of the localization error for each elevation angle and type of noise.

Noise	Elev. angle	Ave.	S.D.	95% prediction interval	
				Upper	Lower
Low-pass	55°	3.5°	8.9°	21.1°	−14.1°
	65°	2.3°	10.0°	22.1°	−17.5°
	75°	4.2°	15.7°	35.4°	−27.0°
	80°	7.3°	23.2°	53.3°	−38.8°
Wide-band	55°	1.4°	8.4°	18.0°	−15.3°
	65°	1.7°	9.5°	20.5°	−17.1°
	75°	4.0°	13.2°	30.2°	−22.2°
	80°	1.8°	17.4°	36.4°	−32.8°

Table 3: p-Values of the F-test (*p <0.05) between the variances of the localization error.

Between the same noises				Between low-pass and wide-band	
		Low-pass	Wide-band		
55°	65°	1.69×10^{-1}	1.54×10^{-1}	55°	5.16×10^{-1}
	75°	4.89×10^{-11}*	1.51×10^{-7}*	65°	5.49×10^{-1}
	80°	2.20×10^{-16}*	2.20×10^{-16}*	75°	4.02×10^{-2}*
65°	75°	1.30×10^{-7}*	1.06×10^{-4}*	80°	7.94×10^{-4}*
	80°	2.20×10^{-16}*	3.15×10^{-12}*		
75°	80°	5.92×10^{-6}*	1.18×10^{-3}*		