An Experimental Investigation about the Perception of a Sound Source with Moving Its Width

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Abstract—**In this paper dynamic characteristics were investigated of the perception of a sound image width. Subjective evaluation tests were carried out of the width of a sound image when its presentation region was moved in the horizontal plane. As a result, the sound image width was perceived narrower or wider than the actual presentation region when the sound source width was decreased or increased, respectively. The result obtained shows that a phenomenon which is a kind of auditory motion aftereffects was occurred in the perception of a sound source with changing its width.**

I. Introduction

After adapting to a sound stimulus moving at a certain speed, a stationary sound stimulus is perceived to move in the direction opposite to that of the moving stimulus. This phenomenon is known as an auditory motion aftereffect[1]. A great deal of effort has been made on auditory motion aftereffects[1]–[4]. What seems to be lacking, however, is to take the width of a sound image into consideration. In such a situation it is necessary to investigate dynamic characteristics of the auditory perception include the effect of changing its source width.

This paper is intended to obtain a basic knowledge about dynamic characteristics of the perception of a sound image width. For this purpose we performed subjective evaluation tests of a sound source with moving its width in the horizontal plane.

II. Experiment

In order to investigate dynamic characteristics of the perception of a sound image width, we carried out subjective evaluation tests of the width of a sound image whose source width changed in the horizontal plane.

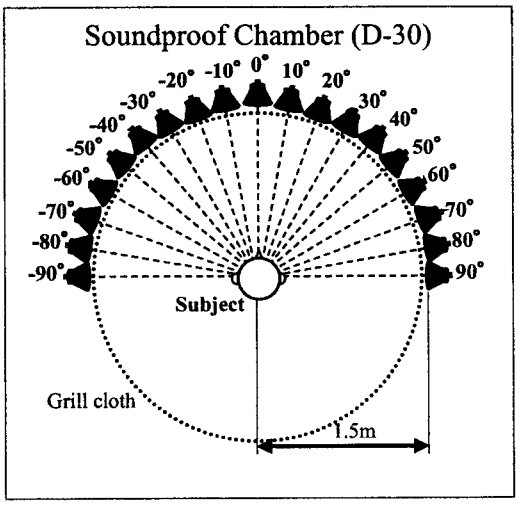


Fig. 1. Arrangement of the loudspeakers.

A. Apparatus and Stimulus

The subjective evaluation tests were performed in a soundproof chamber (D-30, 4.3 m (W) × 3.7 m (D) × 2.5 m (H)). In the chamber, 19 loudspeakers were arranged semicircularly every 10 degrees in front of a subject, i.e., it was possible to reproduce the sounds from the directions of −90, −80, ..., −10, 0, 10, ..., 80, and 90 degrees. **Figure 1** shows the arrangement of the loudspeakers. The distance between each loudspeaker and the subject was 1.5 m. A cylindrical-shaped black grill cloth at a radius of 1.4 m was hung from the ceiling to hide the loudspeakers from the subject's view.

A pink noise of 20 Hz to 20 kHz was used as the sound stimulus. Three of the arranged loudspeakers were used to reproduce the sound stimulus. The sounds from the left and right loudspeakers were delayed at 10 ms and 20 ms, respectively, rather than the sound from the center loudspeaker in order to obtain a sound image with a

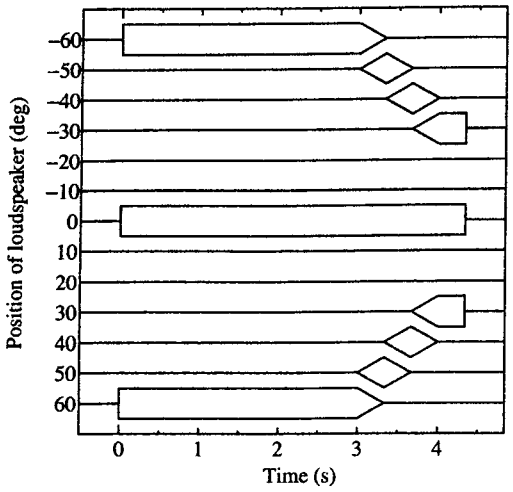


Fig. 2. Amplitude transitions of the input signals to each loudspeaker.

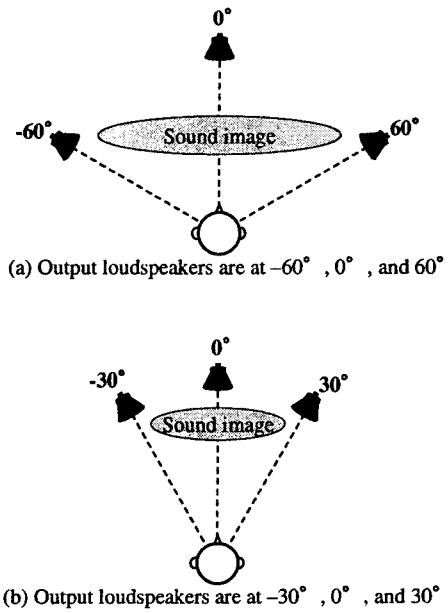


Fig. 3. Movement of the sound image width.

wide width[5], [6]. Movements of the sound image width were simulated by means of changing the output channels to the left and right loudspeakers. **Figure 2** shows an example of the amplitude transitions of the input signals to each loudspeaker. Then the sound image width changes as shown in **Fig. 3.**

A subject was seated on a chair placed at the center of the arranged loudspeakers. The head of the subject was fixed using a headrest installed in the chair.

B. Subject

Five males, aged 21 to 23 years, were employed as the subjects of the experiment. All subjects had normal hearing acuity.

C. Procedure

We presented the sound stimulus to each subject. There were three kinds of conditions of the stimulus presentation as follows:

i) the sound stimulus without changing the presentation region,

ii) the sound stimulus with contracting the presentation region,

iii) the sound stimulus with expanding the presentation region.

The positions of the left, center, and right output loudspeakers in the cases **i)** to **iii)** are shown in **Table 1 (a)** to **(c)**, respectively.

Table 1: Positions of the output loudspeakers (LSPs) of the sound stimulus.

(a) Sound stimulus without changing the presentation region.

Left LSP (deg)	Center LSP (deg)	Right LSP (deg)
−30	0	30
−60	0	60
−90	0	90

(b) Sound stimulus with contracting the presentation region.

	Left LSP Start→End (deg)	Center LSP (deg)	Right LSP End←Start (deg)
#1	−60 → −30	0	30 ← 60
#2	−90 → −60	0	60 ← 90
#3	−90 → −30	0	30 ← 90

(c) Sound stimulus with expanding the presentation region.

	Left LSP End←Start (deg)	Center LSP (deg)	Right LSP Start→End (deg)
#1	−30 ← 0	0	0 → 30
#2	−60 ← 0	0	0 → 60
#3	−90 ← 0	0	0 → 90
#4	−60 ← −30	0	30 → 60
#5	−90 ← −30	0	30 → 90
#6	−90 ← −60	0	60 → 90

In the case of **i)**, the sound stimulus was presented for 3 s. In the cases of **ii)** and **iii)**, the sound stimulus was presented for 3 s at the start position, then the left and right output loudspeakers began to shift at speeds of 90, 60, or 30 (Fig. 2) deg/s, and after the shift the sound stimulus was still presented for 0.11, 0.17, or 0.33 s, respectively, at the end position. All patterns of the presentation were performed in a random order. Each

presentation pattern was performed three times to each subject.

After every presentation we required the subject to answer the perceived width of the sound image with referring to the labels which showed azimuth angle (every 5 degrees) stuck on the grill cloth.

III. Result

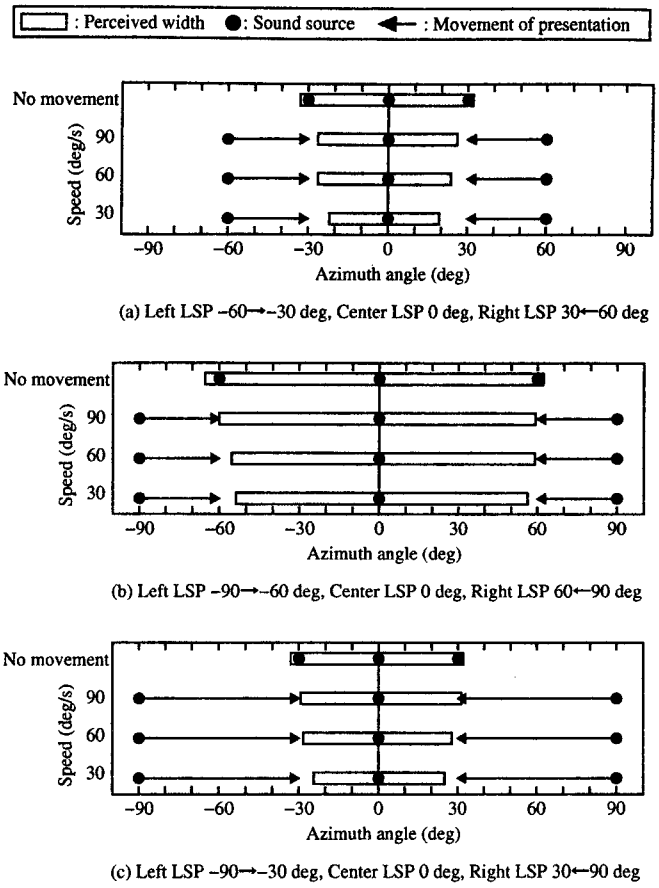
Figures 4 (a) to **(c)** show the results of the perceived width of the sound image in the case of contracting the presentation region. The results of (a) to (c) correspond to the cases #1 to #3 in Table 1 (b). In these figures, a rectangle denotes the perceived width of a sound image, a filled circle denotes an output loudspeaker, and an arrow denotes the shift direction of an output loudspeaker. In each figure, the result of the case without changing the presentation region (Table 1 (a)) is shown at the top, and the results of the case with contracting the presentation region at speeds of 90, 60, and 30 deg/s are shown at the second, third, and fourth, respectively.

The width of the sound image that the subjects perceived is almost as the same as the actual presentation region of the three output loudspeakers at the top in Fig. 4 (a). The perceived width is narrower than the actual presentation region at the second to fourth in Fig. 4 (a), and this tendency is more remarkable as the contraction speed is slower. As well as the case of Fig. 4 (a), the perceived width of the contract case is narrower than the actual presentation region at the second to fourth in Fig. 4 (b) and (c). It is also observed that the perceived width becomes narrower as the contraction speed is slower.

Figures 5 (a) to **(f)** show the results of the perceived sound image width in the case of expanding the presentation region. The results of (a) to (f) correspond to the cases #1 to #6 in Table 1 (c).

In the expand case of Fig. 5 (a), (b), and (d), the subjects perceive the sound image width wider than the actual presentation region. The tendency that the perceived width is wider becomes remarkable as the expansion speed is slower, particularly in Fig. 5 (a) and (b). On the other hand, the expand case in Fig. 5 (c), (e), and (f), where the positions of the left and the right loudspeakers are -90 and 90 degrees at the presentation end, the subjects perceive the sound image width as almost the same as the width in the case of without changing the presentation region.

As the results shown above, the perceived width of a sound image is narrower or wider than the actual presentation region when the sound source width is decreased or increased, respectively, except at the lateral direction of ± 90 degrees. The change of the perceived width is larger as the moving speed is slower, i.e., as the presentation time at the end position of the movement is longer.



(a) Left LSP −60→−30 deg, Center LSP 0 deg, Right LSP 30←60 deg

(b) Left LSP −90→−60 deg, Center LSP 0 deg, Right LSP 60←90 deg

(c) Left LSP −90→−30 deg, Center LSP 0 deg, Right LSP 30←90 deg

Fig. 4. Perceived width of the sound image with contracting the presentation region.

IV. Conclusion

We have investigated dynamic characteristics of the perception of a sound source width. Subjective evaluation tests were carried out of a sound source with changing its width in the horizontal plane.

As a result, the sound image width that the subjects perceived changed to its movement direction (contraction or expansion) more than the actual presentation width. This result obtained shows that a phenomenon which is a kind of auditory motion aftereffects is occurred in the presentation of a sound source with changing its width.

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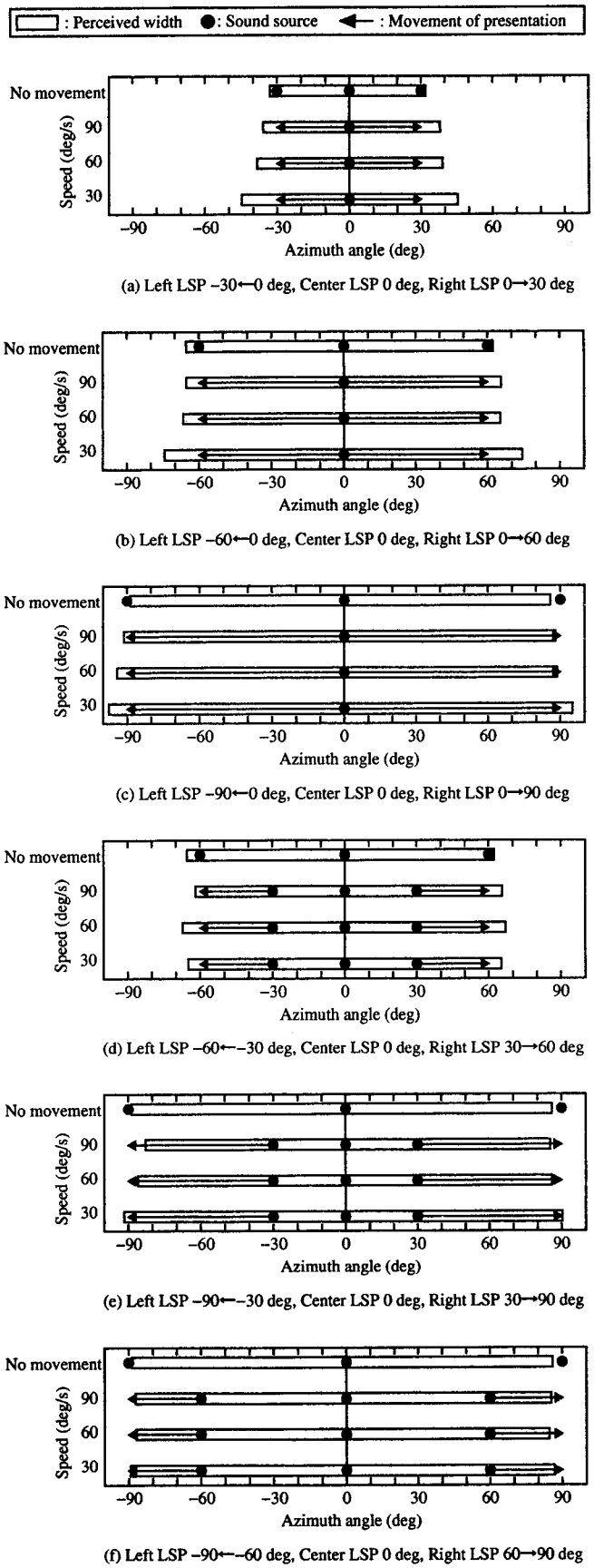

(a) Left LSP –30←0 deg, Center LSP 0 deg, Right LSP 0→30 deg

(b) Left LSP –60←0 deg, Center LSP 0 deg, Right LSP 0→60 deg

(c) Left LSP –90←0 deg, Center LSP 0 deg, Right LSP 0→90 deg

(d) Left LSP –60←–30 deg, Center LSP 0 deg, Right LSP 30→60 deg

(e) Left LSP –90←–30 deg, Center LSP 0 deg, Right LSP 30→90 deg

(f) Left LSP –90←–60 deg, Center LSP 0 deg, Right LSP 60→90 deg

Fig. 5. Perceived width of the sound image with expanding the presentation region.