Study on improvement of sound localization for Dichotic-Listening

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Abstract

Elderly people lose their hearing through decreasing auditory resolution and temporal resolution with aging. Dichotic-Listening is a method that presents different sounds to the right and left ears. One of the methods of Dichotic-Listening is to impart sound that separates F1 frequency and F2 frequency between the right and left ears. This method indicates that hearing of sensorineural hearing impairment improves articulation. However, sound localization of Dichotic-Listening is perceived in different places. Elderly people perceive sound localization on the low-frequency side. Hearing people perceive sound localization in two directions.

In this paper, we propose a method for moving the perceived location of a sound to a subjects's front by mixing low-frequencies and high-frequencies and imparting delay. We studied sound localization by alternately mixing low-frequency and high-frequency sounds in increasing increments of 10% to a total of 50% and to imparting delay, thereby achieving different sound localizations. As a result, our proposed method can move the sound localization to the front of a subject by mixing ratios of 40% and 30% and imparting delay.

Keywords: Dichotic-Listening, sound localization, presbycusis.

Fig. 1 Conceptual diagram of Dichotic-Listening

1. Introduction

Elderly people are increasing early in Japan. Elderly people decrease auditory resolution and temporal resolution with aging. Elderly people develop hearing loss from decreasing in resolution. The hard of hearing uses hearing aid to be easy to understand. However, hearing aid have any problem. One of the problems is that masking by low-frequency to high-frequency has not improved. There is Dichotic-Listening to improve masking. Dichotic-Listening is a method that presents different sounds to the right and left ears. One of the methods of Dichotic-Listening is to impart sound that separates F1 frequencies and F2 frequencies between the right and left ears^(1,2). Figure 1 shows a conceptual diagram of Dichotic-Listening. On the other hand, we identify the position of sound through the use of sound localization. Moreover, localization of the position of sound allow perceiving alert. However, sound localization of Dichotic-Listening is perceived in different places. Elderly people perceive sound localization on the low-frequency side. Hearing people perceive sound localization in two directions⁽³⁾. Therefore, sound of Dichotic-Listening difficult to identify the position of sound. We consider important to moving the sound localization to original position.

Fig. 2 Conceptual diagram of delay

In this paper, we propose a method of moving the sound localization to perceive in front by mixing low-frequencies and high-frequencies and imparting delay. We discuss the effects of the proposed method on sound localization.

2. Improvement of Dichotic-Listening

2.1 Method I (Mixing)

Conventionally Dichotic-Listening method separates perfect (Left ear: imparts low-frequency 100%, Right ear: imparts low-frequency 100%) into low-frequency and high-frequency. We consider that it should impart much the same sound to right-and-left ears to move sound localization. Here, we propose method that we present sound mixed low-frequency (Dichotic-L) with high-frequency (Impart-L) to left ear at a constant rate. Similarly, we present sound mixed high-frequency (Dichotic-R) with low-frequency (Impart-R) to right ear at a constant rate.

Table 1. Subjects Data

Subjects	Age	Average hearing level (L,R)[dB]
A	75	(43.8,43.8)
B	73	(26.3,21.3)
C	72	(25.0,22.5)
D	72	(27.5,21.3)
E	76	(48.8,48.8)
F	72	(46.3,46.3)

Table 2. Filter Conditions

condition	Left	Right
① (Basis)	High: 0[%] Low :100[%]	High:100[%] Low : 0[%]
②	High: 10[%] Low : 90[%]	High: 90[%] Low : 10[%]
③	High: 20[%] Low : 80[%]	High: 80[%] Low : 20[%]
④	High: 30[%] Low : 70[%]	High: 70[%] Low : 30[%]
⑤	High: 40[%] Low : 60[%]	High: 60[%] Low : 40[%]
⑥	High: 50[%] Low : 50[%]	High: 50[%] Low : 50[%]

2.2 Method II (Delay)

If the sound localization is moved by Dichotic-Listening, we consider it possible to replace the sound localization by imparting delay to the right and left ears. Figure 2 shows a conceptual diagram of delay. Here, we propose a method that imparts delay to Dichotic-L to move the localization to the front. Similarly, we impart delay to Dichotic-R to achieve the same effect. Delay imparted to Left sound (Right-sound) was calculated based on the result of method I⁽⁴⁾.

3. Assessment Experiment

3.1 Subjects

Subject are three young adult people (male: age 23~24) and six elderly people (male: age 72~76). Table 1 shows the subjects data. All subjects not normally using hearing aid. Average hearing level is calculated based on the quartation.

3.2 Experiment condition

We used recordings of male speakers reading phoneme balanced sentences, recorded at a sampling frequency of 16 kHz for continuous research for the speech database VOL1, as the sounds for using in the assessment. We applied low-pass and high-pass filters to sounds for Dichotic-Listening. The frequencies in Dichotic-Listening are separated into 0.8 kHz and 1.6 kHz ⁽⁵⁾.

Assessment sounds use six different mixing ratios. Table 2 shows the mixing ratios. We performed experiments in the following two kinds.

<Experiment I>

The evaluation of method I uses six kinds of mixing methods. This processing mixes to keep power balanced in all assessment sounds and increases by 10% from the base level (① of Table 2) up to 50% (⑥ of Table 2).

<Experiment II>

The evaluation of the method II used four kinds of delay and the conditions ①~⑥ of Experiment I. We calculated delay on the basis of the result of the Experiment I so as to move the localization to the front. We imparted delay to Dichotic-L (Dichotic-R) of conditions ②~⑤.

Here, a set id defined as a combination of six mixing conditions and two separating frequencies. We presented three sets in random order to each subjects. We performed only experiment I at separating frequency 0.8 kHz on elderly people.

3.3 Listening Experiment

The experiment was performed in the acoustic room. The assessment sound was imparted to subjects by headphones. The space in front of the subject is defined as zero degrees, plus (+) refers to subject's right side and minus (-) refers to the left side. Moreover, the loudness of the assessment sound consisted of 9 levels from 0 to 8. The baseline was level 4. We informed subjects that they would be asked to provide an answer about hearing assessment sound direction ($-90^{\circ}\sim 90^{\circ}$) and loudness (0~8). We alternated presentations with sounds made in front of the subject and sounds prepared by the proposed method.

4. Result

4.1 Experiment with Young Adult

Figures 3 and 4 shows the averages of the results of all adult subjects of each experiment. The horizontal axis indicates the separating conditions, the vertical axis indicates hearing assessment sound direction, the size of the circle indicates loudness and the bar indicates standard deviation. As can be seen from the Figure 3, sound localization moves to be perceived as coming from the front with increased mixing ratio. Moreover, sound localization was perceived as unidirectional bidirectional depending on the mixing ratio.

Next, delay was derived from sound direction obtained from experiment. Figure 4 shows the experimental results of imparting delay to Dichotic-L (Dichotic-R). Tables 3 and 4 show this delay. As shown in Figure 4, we were able to confirm the movement of sound localization achieved by imparting delay to sounds for Dichotic-Listening. In particular, sound localization was found to move even more to the front as compared with the same conditions of Experiment I. Moreover, sound localization was perceived at the same point mixed 40% in Experiment I as when sound was mixed 30% in Experiment II. As for imparting delay to Dichotic-Listening, we were able to confirm the effect of delay such that perceived sound localization changed from bidirectional to unidirectional. Moreover, we found loudness on the right side to increase with increasing mixing ratio

4.2 Experiment with Elderly People

Figure 5 shows the average of the results of all elderly subjects of Experiment I. The horizontal axis indicates the separating conditions, the vertical axis

indicates hearing assessment sound direction, the size of circle indicates loudness and the bar indicates standard deviation. As can be seen from Figure 5, subjects perceived sound localization to be coming from in front with increased mixing ratio. However, the standard deviation is extremely wide. Moreover, we found loudness on the left side to increase with increasing mixing ratio.

5. Discussion

About the results of the young adults, subjects perceived sound localization on their right sides when the separation frequency was 0.8 kHz. On the other hand, the subjects perceived sound localization in two directions when the separation frequency was 1.6 kHz. It seems that one reason for this is that young adults are sensitive to frequencies > 0.8 kHz. However, sound localization converged in one direction when the separation frequency was 1.6 kHz. It seems that imparting delay to Dichotic-Listening that mixed low-frequency and high-frequency is effective for moving sound localization.

About the results of the elderly people, it seems that sound localization varied depending on the sound pressure level of the sound's presentation. In this experiment, we imparted sound at the same level of sound pressure level regardless of the subject's listening level. As a result, subject A, subject E and subject F reported that they could not hear or could hardly hear high-frequency sounds (right ear). Therefore, sound pressure level needs to be adjusted to an optimum listening level tailored to each subject.

Moreover, all subjects reported difficulty in perceiving sound localization. One of the reason seem that the perceived directions disagreeing with real directions as a cause for not normally using hearing aid. Therefore we consider training to match real direction and lateralization to be necessary.

References

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Fig. 3. Experiment I result (adult)

Table 3. Delay (0.8 kHz)

condition	Low [ms]	High [ms]
②	0.66	0.75
③	0	0.64
④	0	0.53
⑤	0	0.21

Table 4. Delay (1.6 kHz)

condition	Low [ms]	High [ms]
②	0.72	0.78
③	0.50	0.69
④	0.34	0.53
⑤	0.28	0.16

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Fig. 4. Experiment II result (adult)

Fig. 5. Experiment I result (elderly people)

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