Study of Word Intelligibility Based on Control of ITD or ILD on Binaural Hearing

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Abstract

Through current hearing aids research, it is possible to wear hearing aids in both ears, and hearing-impaired individuals have been found to obtain a binaural effect equivalent to that of hearing individuals. In this study, it is assumed that hearing aids are being worn in both ears, and the study focuses on the direction of the sound.

This study assumes that hearing aids are being worn in both ears, and focuses on the direction of the sound. If other noise is present near the target sound, we consider whether the clarity of the target sound can be improved by applying a noise removal process, a process which gives a sense of direction to the target sound (Inter-aural Time Differences, Inter-aural Level Differences, etc.) and separates the sound images of the target sound and the noise.

In this paper, the subjects consisted of both younger adults and elderly individuals; we performed a word intelligibility experiment to assay changes in word intelligibility in the case of performing inter-aural time difference to the target sound. In the result obtained from the younger adults, word intelligibility increased by giving a sense of direction other than 0 °. In the case of the hearing level of elderly individuals, both ears decreased; the same tendency as that of the younger adults was not observed; instead, the trend differed with each subject. By changing the left-right balance, it was found that word intelligibility was improved despite lowered listening sound level per ear. It is compared with the condition in which left-right balance has been taken with the conditions changed. In younger adults, the word intelligibility has increased when lowering the right. In elderly individuals, when they also lowered the left or right, word intelligibility was improved.

Keywords: hearing aids, ITD, ILD.

1. Introduction

In previous studies, hearing-impaired individuals preferred to wear hearing aids in both ears in order to approach the level of hearing similar to that of hearing unimpaired individuals. Subjects desired to wear hearing aids in both ears are underway\textsuperscript{(1,2)}. In this study, we examined a system which supports a level of hearing of the hearing-impaired individuals’ ability to hear with background noise.

When hearing unimpaired individuals listen to target sounds and noises, we understand characteristics of the sound by a sense of direction due to the time difference, the level difference between both ears, the harmonic structure of the sound, and the temporal change pattern\textsuperscript{(3)}. However, if the target sound source and noise sound source are present in the same direction, we can determine them only by the characteristics of the sound because we cannot have ascertained any clues using our sense of direction. Thus, hearing-impaired individuals were not able to accurately distinguish the characteristics of the target sound and it was difficult for them to hear the target sound. Insufficient improvement was observed in the case of wearing hearing aids. Therefore, for those who are hard-of-hearing who have been wearing hearing aids in both ears, we give a sense of direction due to the time difference or sound level difference between both ears to the target sound, and we propose a system which separates the sound image of the target sound and noise in the front.

In this paper, we extract only the target sound from the sound mixed target sound and noise in the same direction, evaluate whether to improve the hearing of the target sound
to be played by giving the sense of direction by the word intelligibility test.

2. Overview of System for applying sense of direction

Fig. 2. shows a summary of the sense of direction grant system to be proposed. The mixed sound of the noise and desired speech coming from the same direction, to extract only the sound subjected to sound separation, it is reproduced from the receiver by applying a sense of direction to the target speech. In this paper, the stationary noise is assumed to be noise, using spectral subtraction method (SS method) as a sound source separation method. In addition, as the method of applying the sense of direction, it will be examined two types of inter-aural time difference (ITD), both ears Mahon pressure difference (ILD). In order to verify the hearing improvement grant to target speech a sense of direction by the ITD and ILD, to perform the word intelligibility test.

3. Consideration of the effect of applying a sense of direction

3.1 Experimental condition

Fig. 1. System for applying a sense of direction.

Table 1. Subject’s average hearing level.

<table>
<thead>
<tr>
<th></th>
<th>Left ear(dB)</th>
<th>Right ear(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Younger adult 1</td>
<td>0</td>
<td>-1.25</td>
</tr>
<tr>
<td>Younger adult 2</td>
<td>2.5</td>
<td>-1.25</td>
</tr>
<tr>
<td>Younger adult 3</td>
<td>11.25</td>
<td>2.5</td>
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<tr>
<td>Younger adult 4</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Younger adult 5</td>
<td>6.25</td>
<td>3.75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Left ear(dB)</th>
<th>Right ear(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elderly individual 1</td>
<td>42.5</td>
<td>36.25</td>
</tr>
<tr>
<td>Elderly individual 2</td>
<td>31.25</td>
<td>30</td>
</tr>
<tr>
<td>Elderly individual 3</td>
<td>42.5</td>
<td>46.25</td>
</tr>
<tr>
<td>Elderly individual 4</td>
<td>27.5</td>
<td>30</td>
</tr>
<tr>
<td>Elderly individual 5</td>
<td>28.75</td>
<td>20</td>
</tr>
</tbody>
</table>

Subjects included five men in their 20s and 70s, and the experiment was conducted in a sound-proof room. Fig. 1 shows the positional relationship between the subject and the sound source. Table 1 is the average hearing level of the subjects. Moreover, this experiment was conducted using MX375 (SENNHEISER) intra-concha type earphones, without hearing aids, in order to assay only the effect of improvement in the clarity of sound. We conduct a spectral subtraction method, which is a noise removal method for sounds that mix the target sound and other noises. A sound which gave a sense of direction using time difference to the target sound was played from the earphones. In this case, the subjects heard the direct sound from the reproduced sound and the loudspeaker from the earphone at the same time. Typically, as in Fig. 3. (a), the reproduced sound is added to the sum of the time of the sound taken from the target sound source to the subject (τ1) and the internal processing delay in the hearing aids (τ2). This time in Fig. 3.
(b) this value was calculated by adding the two delayed audios to be reproduced or earphones

To make it easier to perceive the sense of direction, a recording saying the words "NTT • Tohoku parent density by word intelligibility test for voice data set 2007 (FW07)" was utilized as a target sound, with pink noise used as the noise\(^4,5\). The relationship between the inter-direction pattern and the delay time is 15 cm between both ears in this experiment as shown in Table 2. To confirm the change in word intelligibility of the correct answer rate, we set the SN of the loudspeaker to -5 dB for the case where subjects are younger adults, and to + 5 dB in the case where subjects are elderly individuals. Moreover, the sound pressure of each word in the word list, because have been made sound pressure correction for each word so as not to de difference in correct answer rate among the list, the sound pressure of the target speech to which were averaged sound pressure of each word I was.

### 3.2 Consideration of the effect of applying a sense of direction by ITD

As sense of direction of the pattern shown in Table 2, the time difference between the left and right are used seven patterns obtained by changing the time difference to be 30 ° increments. Time difference between the time it was calculated inter-aural as 15 cm. Is carried out three times a word intelligibility test for each pattern, shows the average of the word intelligibility of each direction of the adults and the elderly in Fig. 3. As a result, in adults, slightly improved it was observed word intelligibility by giving a sense of direction other than 0 °. On the other hand, in the case of the elderly, rose with is greater than adults, was greater variation also in the results of each individual. From this fact, in the elderly, it is conceivable that difficult out difference than adults by lowering and lowering of the hearing level of sense of direction perception ability.

### 3.3 Consideration of the effect of applying a sense of direction by ILD

ILD is different from the time difference, since the correspondence between the sound source direction is not known, the standard ones (LR) which is taken is left-right balance, nine pattern that attenuates the sound pressure of the left ear or the right ear with 25% increments We were using the voice. Sense of direction of the pattern I is shown in Table 3. Is carried out three times a word intelligibility test for each pattern, shows the average of the word intelligibility of younger adults and elderly individuals (ILD).
intelligibility of each pattern of adults and the elderly in Fig. 4. As a result, by changing the left-right balance, it was found that improved word intelligibility despite lowered listening sound pressure per ear. If the left-right balance had 0.00 as compared to (LR), when in adults to lower the right, with improved word intelligibility even when lowering the left or right in the elderly. Thus, the reduced elderly hearing, it is possible to make a head localize a sound image of the target speech to the left or right by the ILD, it can be expected that hearing is improved. In most hearing level of bad elderly, most improvement was seen. The results are shown in Fig. 5. The subject from hearing level of each frequency band in Fig.6, and dropped the hearing level of the high frequency, it can be seen that the consonant becomes difficult to hear. Therefore, the possibility that the sense of direction given by the ILD is to improve the hearing of consonants can be considered. Also, there are left-right difference in the improvement effect is believed to be that it is the influence of the subject's ears handed. The improvement effect is a difference between right and left is considered to be that it is the influence of the subject's ears handed.

4. Conclusions

In this study, it is assumed both ear hearing aids, was carried out verification of hearing the effect of improving the target speech that have been granted a sense of direction by the ITD and ILD. As a result, in the adult, ITD, was improvement of word intelligibility is expected to give a sense of direction by the ILD. In the elderly, improvement by ITD was, observed, improvement of word intelligibility was observed If you give a sense of direction by the ILD. In the future, assuming the fitting of the hearing aid, it is planned to conduct a study of the case of keeping the left and right hearing level the same.

Acknowledgment

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References

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