Evaluation of aided binaural processing in children with hearing impairment by integration and segregation tasks

Tatsuo Nakagawa

Yokohama National University, Faculty of Education and Human Sciences, 79-2 Tokiwadai Hodogaya-ku, Yokohama 240-8501, Japan

Aided binaural processing in children with various hearing levels was evaluated using binaural integration and segregation tasks. The binaural integration task evaluated children's integration of low-pass and high-pass filtered words. The binaural segregation task compared children's performance between monaural and binaural listening conditions. In the monaural listening condition, words were mixed with speech-shaped noise with different signal-to-noise ratios (SNRs). In the binaural listening condition the speech plus noise was delivered through different speakers with the same SNR. Children's word-identification scores were compared for these two conditions. Results indicated that for the binaural integration and segregation tasks, children with symmetrical hearing loss less than 90 dB HL performed well. However, if the hearing levels were greater than 90 dB HL performance on binaural listening tasks decreased even if the child was wearing hearing aids on both ears. If there was a large difference in hearing level between the ears and the child was aided unilaterally, the results indicated difficulty in identifying words in varying degrees of noise.

INTRODUCTION

The advantages of binaural hearing over monaural hearing are well documented, these include improved speech recognition in noise, localization ability, improved sound quality, loudness summation and others advantages (Mencher and Davis, 2006). Many studies have also recognized the advantages of bilateral amplification in people with hearing impairment, although for certain conditions better performance is obtained with unilateral rather than with bilateral amplification (Jerger *et al*., 1993). In this study, we propose a method of evaluating aided binaural processing in children with hearing impairment. The intent is to evaluate bilateral amplification effects in children wearing hearing aids (or a cochlear implant) by measuring word identification for monaural and binaural listening. For the binaural integration tasks, we searched for conditions where bilateral amplification is advantageous relative to unilateral amplification. For the binaural segregation tasks, we investigated conditions where bilateral amplification is disadvantageous.

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METHOD

The subjects of the study were 18 children with various hearing levels. Figure 1 shows their mean hearing levels for right and left ears. Fourteen of them wore hearing aids in both ears. There were no children with bilateral cochlear implants in this study. Remaining 4 children wore one hearing aid or a cochlear implant in one ear.

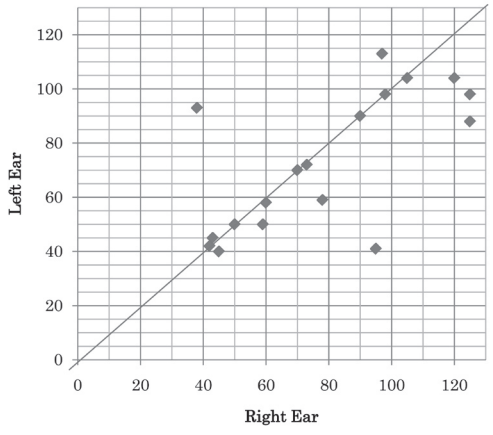

Fig. 1: Subjects' mean hearing levels for the right and left ear.

Binaural integration and segregation tasks were used. The subjects wore special binaural headphones while wearing their hearing aids or cochlear implants. They were asked to identify words presented binaurally or monaurally from each headphone randomly. The presentation levels were 65 to 70 dB (SPL) at the microphone of each prosthesis device.

Binaural integration task

The stimuli were 20 familiar words. The stimuli were digitally-filtered and divided into a low-pass and a high-pass band, respectively. The dividing frequency was 1.3 kHz and the attenuation rate was 36 dB/octave. After filtering the stimuli, we did not manipulate presentation levels between low and high-pass bands. There were 6 listening conditions for the binaural integration tasks (1. Right ear; 2. Left ear; 3. High-pass; 4. Low-pass; 5. Right ear high-pass, left ear low-pass; 6. Right ear low-pass, left ear high-pass). In the monaural listening condition, low-pass or high-pass filtered bands of the words were presented in each ear randomly. In a binaural listening condition, low-pass or high-pass filtered bands of the words were presented in both ears simultaneously. In each condition, subjects were asked to identify the stimuli orally.

Binaural segregation task

The stimuli used in this task were the same as for the binaural integration tasks. An interfering noise was used in the condition. The noise was a multi-talker babble in which 6 male and female adults read from different books. The presentation was divided into two conditions. In one condition, which was called the "mixed condition", the words and noise were mixed and presented in each ear monaurally. The second condition, called the "segregation condition", the words and the noise were presented separately from different headphones. For each condition, 4 SNRs (+3, 0,-3, and -6 dB) were used. The mean RMS level of each word and of the corresponding noise were used in determining the SNR individually for each test word.

RESULTS

Children with mean hearing levels below 90 dB showed different word identification scores than children with mean hearing levels more than 90 dB. Figures 2 and 3 show word identification data for binaural integration and segregation tasks for 9 children who wore two hearing aids and had below 90 dB mean hearing levels for both ears. Figure 2 shows that the word identification scores exceeded 80% for all of the children on the binaural integration tasks. Two children got higher scores in the low-pass condition than in the high-pass condition, but there was no significant difference between ears. Figure 3 shows that the scores were poorer for the mixed condition compared to the segregation condition and that the difference between the two conditions increased with decreasing SNR.

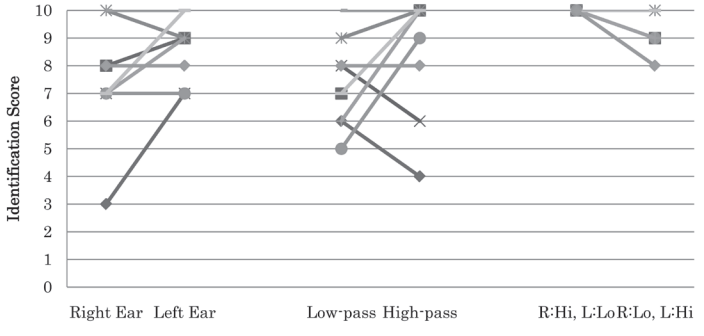

Fig. 2: Word-identification scores in binaural integration tasks for children with mean hearing levels below 90 dB.

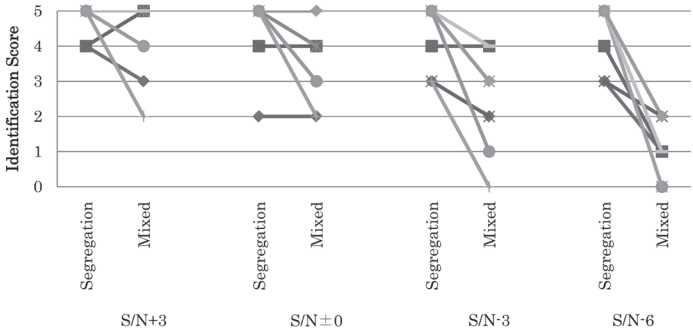

Fig. 3: Word-identification scores in binaural segregation tasks for children with mean hearing levels below 90 dB.

Figures 4 and 5 show word identification data for binaural integration and segregation tasks for 4 children who wore hearing aids or cochlear implants and had more than 90 dB mean hearing levels. Figure 4 shows that the word identification scores were different between filter conditions and amplified ears. Figure 5 shows poor word identification scores for all SNRs.

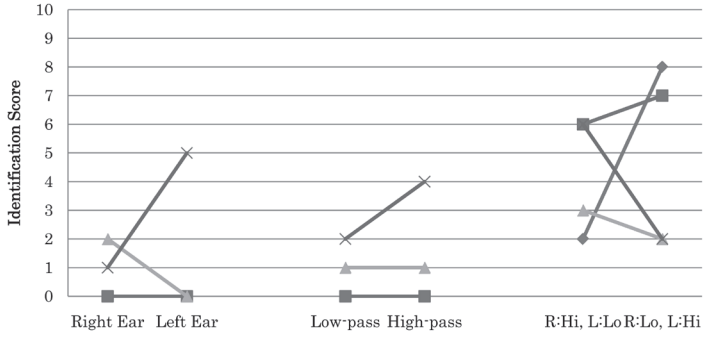

Fig. 4: Word-identification scores in binaural integration tasks for children with mean hearing levels greater than 90 dB.

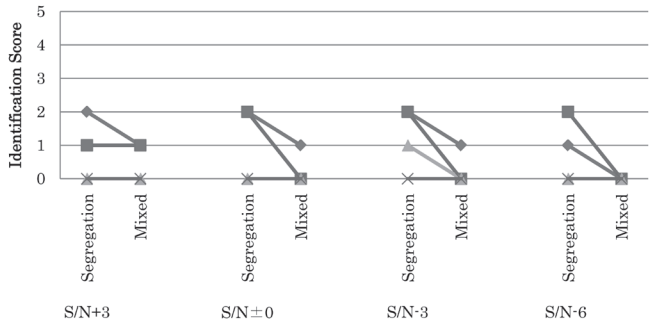

Fig. 5: Word-identification scores in binaural segregation tasks for children with more mean hearing levels greater than 90 dB.

Figure 6 and 7 show word identification data for binaural integration and segregation tasks for 7 children with a difference in mean hearing level between ears of more than 15 dB. Some children were amplified bilaterally and others were amplified unilaterally. The word identification scores for bilateral amplification were not always better than those for unilateral amplification. They were also differences between filter conditions and amplified ears. There were no consistent effects of bilateral amplification. Figure 7 showed word identification scores decreased with decreasing SNR, but the effect was not as marked as that shown in Fig. 3.

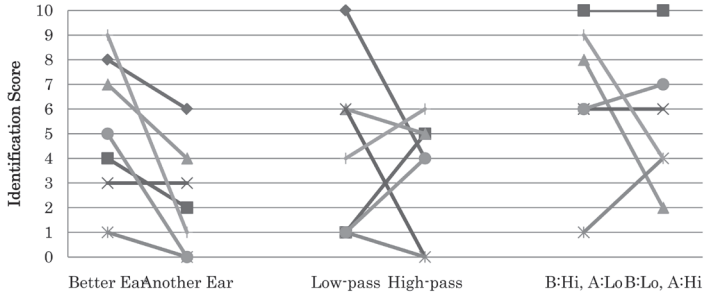

Fig. 6: Word-identification scores in binaural integration tasks for children with more than 15 dB difference in mean hearing level between ears.

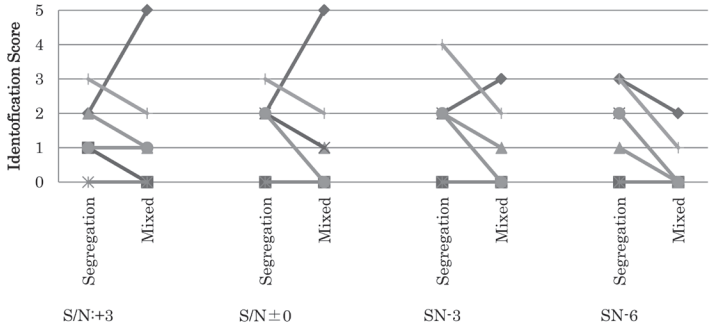

Fig. 7: Word-identification scores in binaural segregation tasks for children with more than 15 dB difference in mean hearing level between ears.

DISCUSSION

Children with mean hearing levels below 90 dB and with bilateral amplification are able to integrate and segregate successfully because their word-identification scores for the binaural listening condition are better than those for the monaural listening condition. For children with mean hearing levels greater than 90 dB showed poor word identification scores of less than 50%. Their performance with bilateral amplification did not necessarily improve relative to unilateral amplification condition, and there were some differences between the amplified ears and filtering conditions. This indicates they cannot effectively integrate or segregate different stimuli presented in each ear even if he or she wears prosthetic devices in both ears.

Two children, who wore hearing aids in both ears, did not show obvious differences in their word identification scores between the binaural and monaural listening conditions. Another two children who wore a cochlear implant and a hearing aid in each ear, respectively, could not identify the low-passed or high-passed words presented in each ear, but their performance improved when they listened to the stimuli binaurally. There was no difference between the two bilateral amplification conditions for one of the two subjects. The subject seems to integrate two different kinds of stimuli. Another subject performed better in one condition where low-pass filtered speech was presented to the right ear and high-pass filtered speech was presented to the left ear than the opposite condition. This may have resulted from cross-hearing. The subject wore a cochlear implant in the right ear and may have heard the low-pass filtered speech when presented in the left ear so as to obtain improved word identification scores.

Children with between-ear differences in mean hearing level greater than 15 dB have difficulty with binaural integration and segregation, particularly for binaural segregation cross-hearing may take place in the better ear. In this case, the noise suppression function of a hearing aid seems most effective.

In summary, this study compared the relative importance of mean hearing level and the difference in mean hearing level between ears in binaural integration and segregation tasks. The experimental results indicate that the former might be a more detrimental factor than the latter in this experimental framework.

ACKNOWLEDGEMENTS

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