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EFFECTS OF TEMPORAL FACTORS ON THE SPEECH PERCEPTION OF THE HEARING IMPAIRED

-- A PRELIMINARY REPORT --

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Introduction

The defective speech perception of patients with sensorineural hearing impairments cannot be fully explained only by a loss in pure-tone sensitivity. It must also be examined in terms of frequency selectivity, temporal acuity and other auditory functions[1]. The relationship between temporal acuity and speech perception, however, has not been sufficiently elucidated. The purpose of the present paper is to report some preliminary results suggesting a close relationship between temporal acuity and speech perception for the hearing impaired.

Although the effects of a loss of temporal acuity on speech perception have been investigated using several psychoacoustic indices, there have not necessarily been consistent conclusions. For instance, Tyler et al.[2] indicated that an increased temporal difference limen and a longer gap-detection threshold correlated significantly with reduced speech intelligibility in noise. On the other hand, Festen and Plomp[3] found only a weak correlation between the width of the psychoacoustic temporal window and the threshold for speech in noise. Instead, they found that hearing loss for speech in noise is related to frequency resolution, while hearing loss for speech in quiet surroundings is related to mean audiometric loss.

Although the psychoacoustic studies mentioned above fail to yield consistent evidence regarding the important role of temporal acuity, we can speculate somewhat using indirect evidence from the literature. Hosoi et al.[4], for instance, reported that failures in consonant perception for the hearing impaired do not seem to be accounted for by pure-tone audiometric loss, while those in vowel perception do seem to be accounted for by pure-tone audiometric loss. Picheny et al.[5,6] reported that speech spoken clearly for the hearing impaired is slower than usual discourse. We may interpret these findings as follows. Many consonants have a shorter duration and weaker intensity than vowels, perhaps especially for in discourse. If patients with hearing impairments have poor temporal acuity or a poor ability to detect short and weak sound segments, while overcoming possible intersegment interactions such as recognition masking, then they would fail to perceive such sound segments. This might be

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true not only for consonants but also even for vowels.

In this paper, as a preliminary report, the effects of temporal factors on the speech perception of the hearing impaired are examined in two experiments. The hypotheses we test are the following, H1: the shorter the duration of a segment is, the lower the intelligibility is; and H2: the shorter the inter-segment interval is, the lower the intelligibility is. H1 is tested in Experiment I, and H2 in Experiment II. As a preliminary report, we use only vowels to simplify the interpretation of the results.

<<Experiment I : Effects of vowel length on intelligibility>>

A. Stimuli

Five japanese vowels spoken clearly by a professional female announcer were digitized through a 12-bit A/D converter at a sampling rate of 20kHz and stored on a micro computer. From the steady part of each vowel waveform, one glottal cycle was extracted. The glottal cycle was repeated continuously to make a vowel segment of a certain length without any fluctuation in the formant and pitch values.

The length of each vowel segment was varied from 20ms to 180ms in 20ms steps by changing the number of repetitions of one glottal cycle. Thus, all stimuli made from a single vowel has constant energy density per glottal cycle even if the length was different. In this way, 45 stimuli were made for five vowels with 9 levels of length. The onset and offset 10ms of each stimulus were linearly tapered to avoid possible click perception. The stimuli were recorded on a magnetic tape through a 12-bit D/A converter using 5 types of randomization.

B. Subjects

The subjects were 6 normal hearing subjects (age range : 20-25 years), 8 sensorineural hearing impaired adults (39-63 years; the range of average hearing levels for the better ears :15-89dB) and 8 sensorinerally hearing impaired children (6-12 years; 76-95dB).

C. Procedures

The stimuli were presented monaurally to the better ear of each subject using an earphone for the normal and hearing impaired adults. For the hearing impaired children, the stimuli were presented by a loud-speaker. The children used their own hearing aids. For the children, the stimuli were limited to three vowels, /a/, /i/ and /o/, with a length of 40ms and 100ms to avoid fatigue and loss of interest.

The level of the stimuli was set at the most comfortable level by each subject. This was about 50dB above the speech reception threshold (SRT). Each subject was instructed to assign one of the Japanese vowels to each stimulus. The intelligibility was calculated as a percentage of the correct responses.

D. Results

The normal subjects showed 100% intelligibility regardless of the length of the stimuli.

Fig. 1 shows the intelligibility as a function of the length of the stimuli for the hearing impaired adults and children. The results for the children are only two scores, at 40ms and 100ms, as mentioned in section C.

For the hearing impaired adults, the intelligibility increases gradually with increasing length between 20ms and 60ms, and is less than that for the normal subjects for the whole length range. The inter-subject differences indicated by the quartile ranges are large.

For the hearing impaired children, there is not a large change in the intelligibility between the lengths of 40ms and 100ms. They have an intelligibility higher than 85%. The inter-subject differences are small.

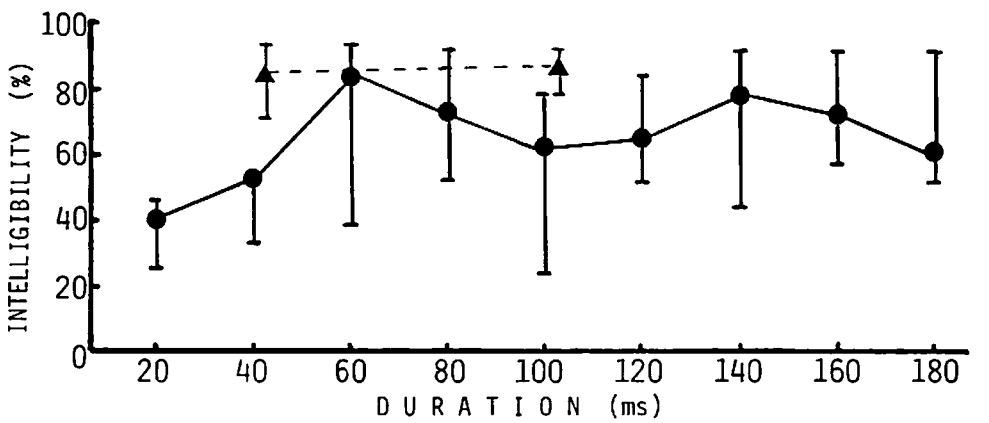

Fig. 1. The relationships between intelligibility and vowel length for the hearing impaired adults (●) and children (▲). The symbols ●, ▲ indicate the medians. The vertical bars represent the quartile ranges.

<<Experiment II: Effects of interstimulus interval on intelligibility>>

A. Stimuli

Using only the stimuli with a length of 100ms and 40ms which were prepared in Experiment I, all possible pairs from the five Japanese vowels were made with silent interval of various lengths between them. The lengths of the silent intervals were set at 0, 40, 80 and 120ms. The length of the first vowel was fixed at 100ms and that of the second one at 40ms, as shown Fig. 2.

B. subjects

The subjects were 8 normal hearing adults, 11 sensorineural hearing impaired children (6-12 years ; 50-110 dB), and 4 sensorineural hearing impaired adults (33-63 years ; 46-80 dB).

C. Procedure

The procedure was the same as in Experiment I.

D. Results

The relationship between the intelligibility and the length of the silent intervals are presented in Fig. 3 and Fig. 4.

Fig.3 shows the results of the normal subjects for the interval length of 0 and 40ms. The normal subjects show almost 100% intelligibility for both the first and second vowels, regardless of the interval length.

The results of the hearing impaired children are shown in Fig.4. The median of the intelligibility for the first vowels, whose length was 100ms, is slightly lower than that for the isolated vowels with a length of 100ms obtained in Experiment I. The median of the intelligibility for the second vowels is lower than that for the first vowels. For the interval lengths of 0 and 40ms, the differences between the intelligibility for the first vowels and that for the second vowels are significant.

In Fig. 4, it can be clearly seen that the median of the intelligibility for the second vowels increases with the length of the silent interval. It approaches the median of the intelligibility for the first vowels, and reaches almost the same value, when the length of the silent interval is 80ms.

Figs 5, 6, 7 and 8 show the results from the two experiments for several individual subjects. These figures show that

the intelligibility for the two-vowel sequences obtained in Experiment II is always lower than the intelligibility for an isolated vowel with a corresponding length which was obtained in Experiment I. Furthermore, as shown in Fig. 5, the intelligibility for the second vowels, which have shorter lengths than the first, is lower than those for the first if the interval length is shorter than 80ms. The intelligibility for the second vowels increases when the interval length increases. Although these figures show numerous differences between the detailed shapes of the curves for the individual subjects, the tendencies noted above are commonly observed.

As shown in Fig. 6 , for some, but not all, subjects, the intelligibility for the first vowels also increases when the interval length increases. As shown in Fig. 7, for some subjects the intelligibility for the second vowels exceeds that for the first if the interval length is longer than 80ms. We show an additional result for a hearing impaired adult in Fig. 8.

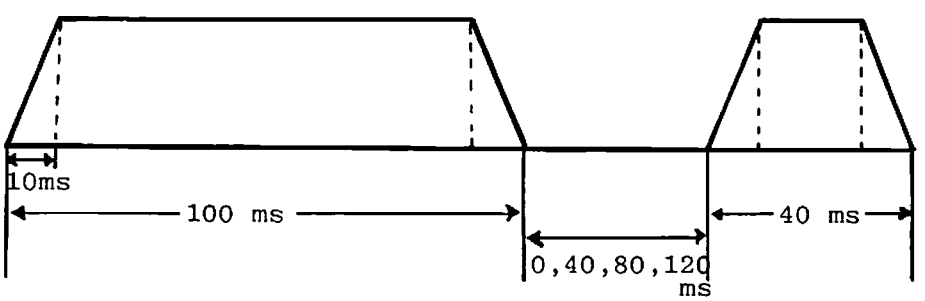

Fig. 2. Temporal sequence of the stimulus used in Experiment II.

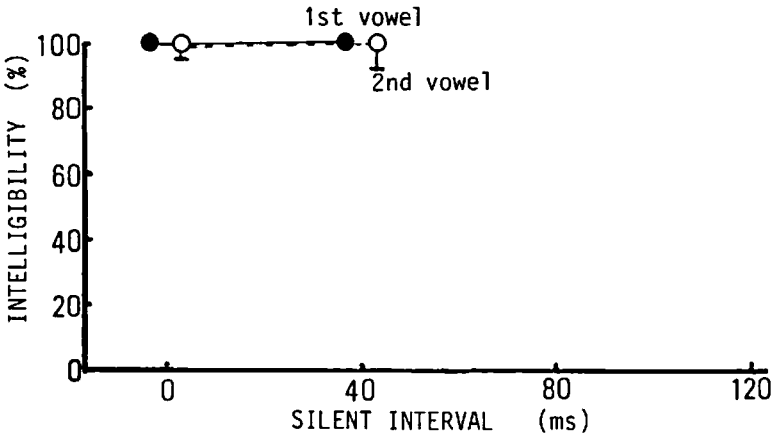

Fig. 3. Intelligibility scores of the normal hearing subjects for the first vowel (●) and the second vowel (○). The symbols ●, ○ indicate the medians. The vertical bars represent the quartile ranges.

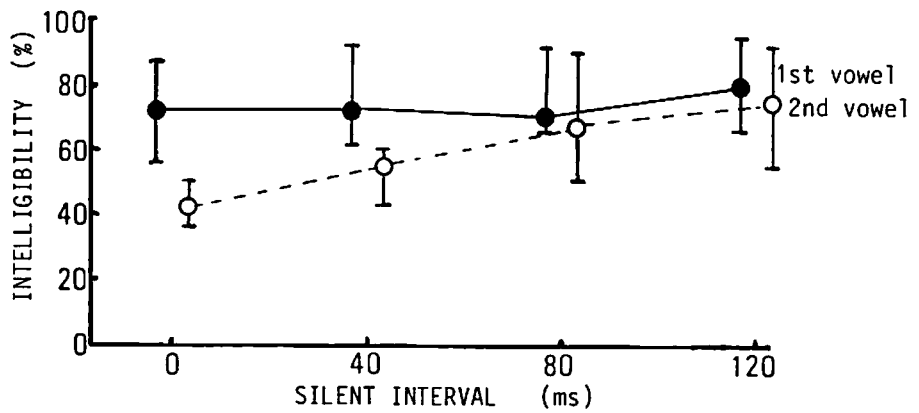

Fig. 4. Intelligibility scores of the hearing impaired children for the first vowel(●) and second vowel (○). The symbols ●, ○ indicate the medians. The vertical bars represent the quartile ranges.

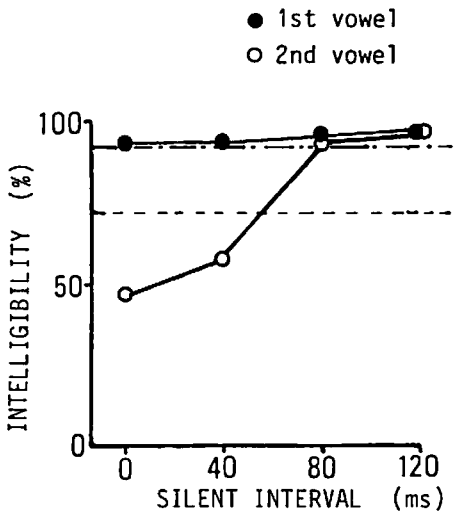

Fig. 5

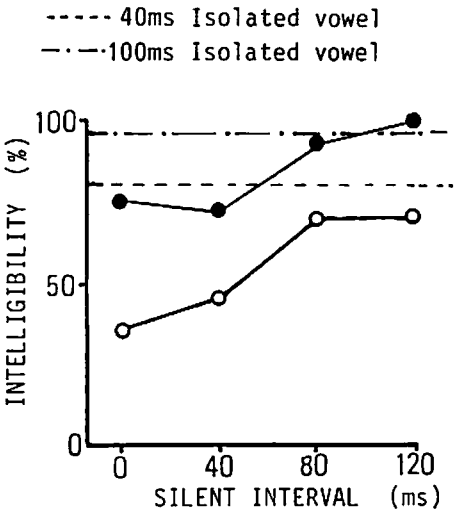

Fig. 6

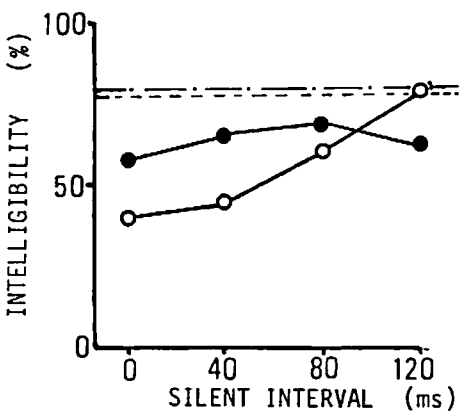

Fig. 7

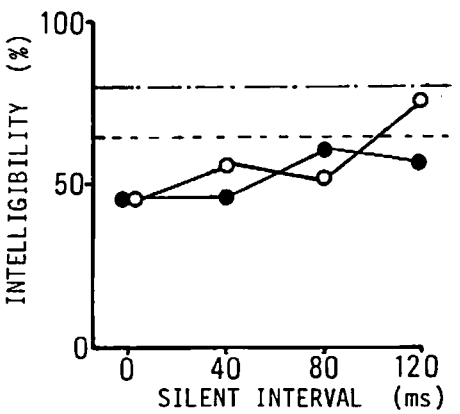

Fig. 8

Figs. 5,6,7,8. The results of Experiment I and II for individual subjects.

Discussion

In Experiment I, we examined the effect of length on the intelligibility of isolated vowels for the hearing impaired. Hearing impaired adults show low intelligibility for lengths below 60ms.

It is well known that duration, T, is an important parameter for the auditory system in terms of integration of energy. For measurements of absolute threshold for intensity, I, one finds that I x T is a constant for a specific range of T between approximately 10 and 200 ms[7,8]. This indicates that the shorter the duration of a vowel with a constant energy density, the lower the loudness. This lower loudness may directly result in lower intelligibility, especially if the stimulus level is around SRT.

The results for Experiment I mentioned above, showing a low intelligibility for durations less than 60ms, may indicate that stimulus duration is critical even though the stimulus level is set at 50dB above SRT for the hearing impaired adults tested here. The shorter the duration of a vowel, the wider the spectrum spreads. So, if patients have a defective frequency selectivity, they should feel greater difficulty in perceiving the shorter vowels. This might be one possible explanation.

Some hearing impaired adults show low intelligibility for durations longer than 80ms (see Fig. 1, 100ms and 180ms, for example), which is lower than the highest intelligibility obtained at 60ms. We do not have any explanation for this phenomenon.

In Experiments I and II, the intelligibility for two-vowel sequences obtained in Experiment II was almost always lower than the intelligibility for the isolated vowels with a corresponding length which was obtained in Experiment I. This result indicates that the presence of another vowel in a approximate timing position significantly affects intelligibility. Thus, this result indicates that interstimulus interactions are significant for the hearing impaired.

Furthermore, it was also shown in Experiment II that the intelligibility for the second vowels, which had a shorter length than the first, was lower than that for the first if the interval length was shorter than 80ms. The intelligibility for the second vowels increases when the interval length increases. For some, but not all subjects, the intelligibility for the first vowels also increases when the interval length increases. The intelligibility for the second vowels exceeds that for the first if the interval length is longer than 80ms.

These results indicate that there must be both forward and backward interstimulus interactions, and the degree of such interactions are dependent not only upon the length of the silent interval but also the vowel duration. The shorter the duration of a vowel and the shorter the interval, the larger the inter-

actions and the lower the intelligibility. In this preliminary report, we can not discuss whether the forward interaction is larger than the backward interaction. This will be presented in the near future.

Therefore, we conclude that the hypotheses H1 and H2 are valid for most, but not all, of the hearing impaired. Of course, we must admit that there are large individual differences in the degree of the effect of temporal factors on the intelligibility of vowels.

Conclusion

For the hearing impaired, we examined two hypotheses. H1: the shorter the duration of a vowel segment, the lower the intelligibility. H2: the shorter the intersegment interval, the lower the intelligibility. Results showed that intelligibility is lower for the shorter vowels and for shorter inter-vowel intervals. Although there are large individual differences, for most, but not all, of the hearing impaired, the hypotheses H1 and H2 seem to be valid.

Acknowledgment

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