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HOW DOES IT SOUND DIPLOPHONIC?

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It is not a rare experience in laryngology to see patients whose voices sound as if they were generated by two separate acoustic sources. Although this type of pathological voice, commonly termed "diplophonia" or "diphonia", has been widely recognized and frequently described[1),2),3),4)], none of the theories proposed at present seems to explain all aspects of this phenomenon.

This may be due, at least in part, to the possibility that a perceptual judgment as diplophonia could be made for various types of physical mechanisms. In fact, some models of diplophonia are apparently contradict each other, particularly in terms of the vibratory mode of the vocal folds.

On the other hand, it is also true that clinicians often identify a voice as diplophonic with ease, even by listening to only a segment of it. For example, listening to the sample tape-recorded voice (code number R2), commercially available to the members of the Japan Society of Logopedics and Phoniatrics[5)], we easily reached a unanimous judgment of diplophonia, especially for portions of sustained /i/ and /u/.

Among various terms to describe hoarse voice, diplophonia is often stated to be correlated with roughness. In fact, the sample voice mentioned above was listed as an example of roughness. Therefore, further research is needed to clarify the relationship between roughness and diplophonia.

As for the pathogenesis of the glottal source producing such bitonality, vocal polyps and nodules, as well as polypoid degeneration (Reinke's edema), are often listed by various authors[1),3)]. In addition, it is also true that there are some patients with definite diplophonia due to either paralysis or paresis of the recurrent laryngeal nerves. This means that the perceptual categorization of diplophonia very likely includes different patterns of pathological vocal fold vibrations, since the physical conditions of the vocal folds are definitely different between polyps and paralysis.

These facts taken together indicate that comprehensive data on diplophonia are still lacking. Even the definition of diplophonia remains open to debate. As part of series of experiments exploring this phenomenon in general, we are examining typical diplophonic voices using of various instrumentations. In this paper, we present some interesting findings associated with the acoustic aspect of diplophonia.

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Figure 1 shows sound oscillograms for the initial portion of a sustained vowel /i/ recorded on a sample tape. A close look reveals that there are two separable groups of oscillation patterns: At the beginning of the utterance, the waveforms gradually increase in amplitude. Then, a kind of modulation in amplitude occurs, followed by a restoration of irregularity after a 0.1-0.2 sec interval. An additional perceptual experiment further revealed that the modulated portions correspond to those of diplophonia. In other words, these modulated portions in the amplitude actually sounded diplophonic.

Figure 2 contains another, higher speed oscillogram for the same period. Here, we determined the fundamental period as the time span between two consecutive timings of local maxima in amplitude, while the value of the amplitude was defined as the length of the vertical line from the peak of a local maximum to the intersection with the connecting line between two neighboring local minima.

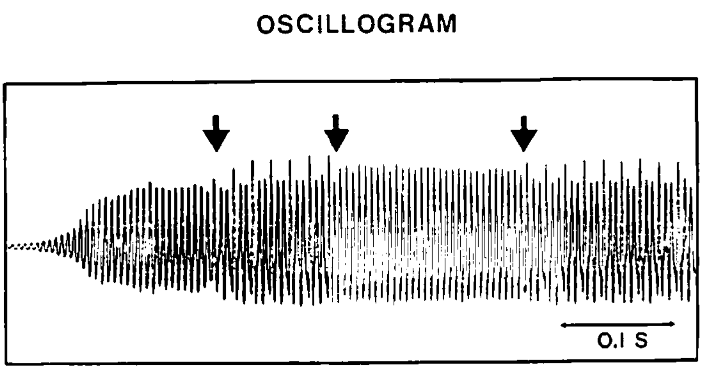

Fig. 1 Sound oscillogram for the initial portion of a sustained vowel /i/

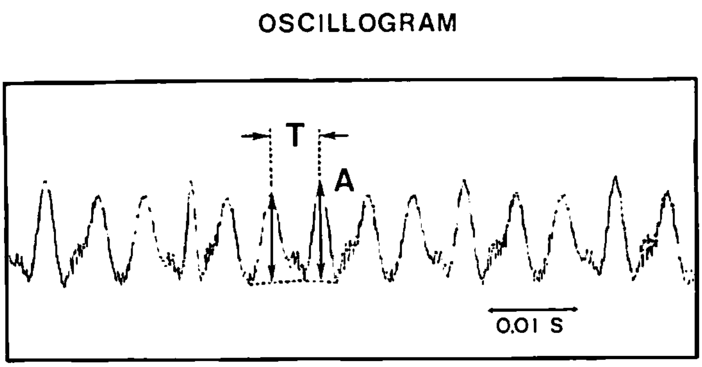

Fig. 2 Another, higher speed oscillogram for the same period in Fig. 1

Figure 3 shows an example of temporal variation in the fundamental period. The arrows indicate the segment which eventually sounded diplophonic. This perturbation curve in the fundamental period demonstrates that one third of waveforms during diplophonic portions are apparently shorter than others. Namely, a short fundamental period follows two similar long fundamental periods.

Figure 4 demonstrates the perturbation curve in the amplitude during a corresponding diplophonic period. Here, it is clear that there are two groups of maximum amplitudes. Among three consecutive waveforms, one is large in amplitude, while the following two are apparently small. Again, this regularity in perturbation is somehow strictly maintained until the end of the diplophonic portion.

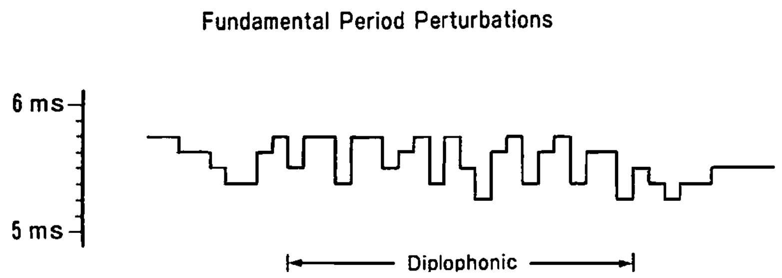

Fig. 3 Perturbation curve in the fundamental period during a diplophonic portion

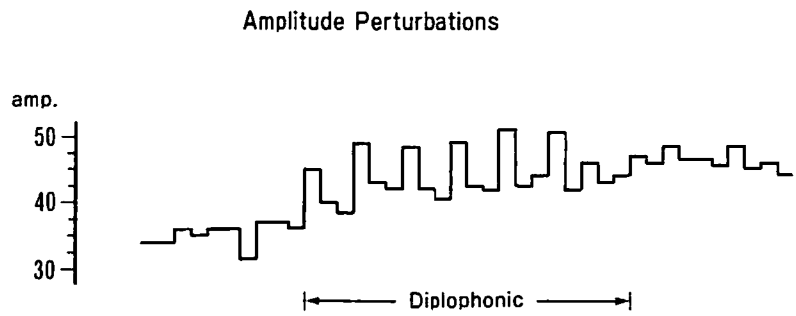

Fig. 4 Perturbation curve in the amplitude during a diplophonic portion

Figures 5 and 6 show the distribution patterns of the amplitude perturbation and fundamental period perturbation, respectively, in 100 consecutive waveforms during diplophonic portions. It is further demonstrated that the group with a large amplitude is definitely separable from the small group. In addition, the short period group is also distinguishable from the long group.

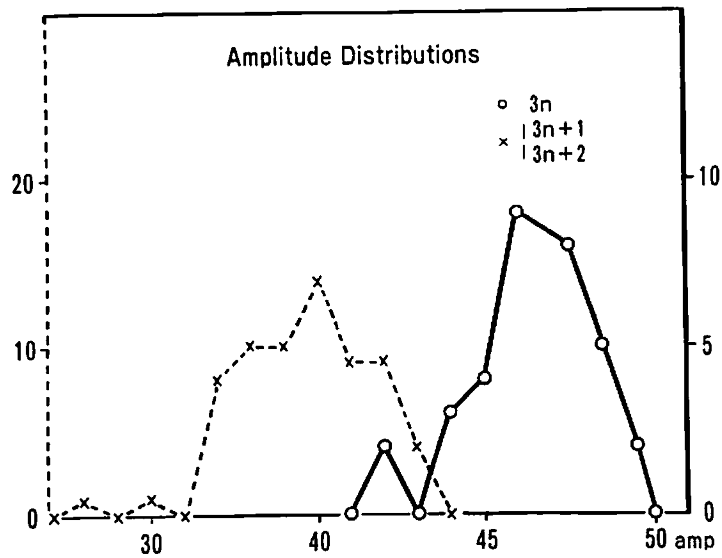

Fig. 5 Distribution patterns of the amplitude perturbation

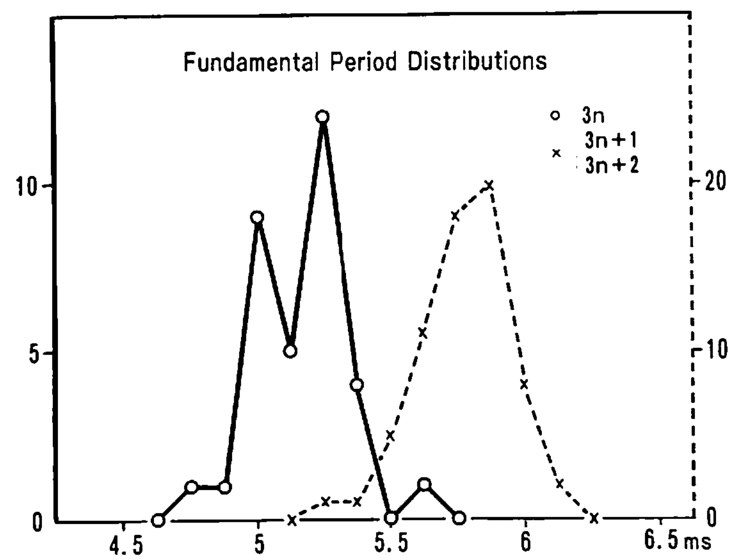

Fig. 6 Distribution patterns of the fundamental period perturbation

These findings indicate that diplophonia may, at least hypothetically, include two components: One is two different patterns in amplitude. The other is two different patterns in fundamental period. Although many authors have emphasized that diplophonia usually contains two distinct pitch patterns, we are rather interested in the possibility of "double amplitude voice". Furthermore, preliminary results of speech synthesis experiments modifying these diplophonic samples are disclosing that amplitude perturbation plays a more important role in diplophonia than fundamental period perturbations. In fact, synthesized voice using a standardization of amplitude does not sound diplophonic, while synthesized voice using a standardization of fundamental period does sound diplophonic. We hope that more details from these synthetic experiments can be reported in near future.

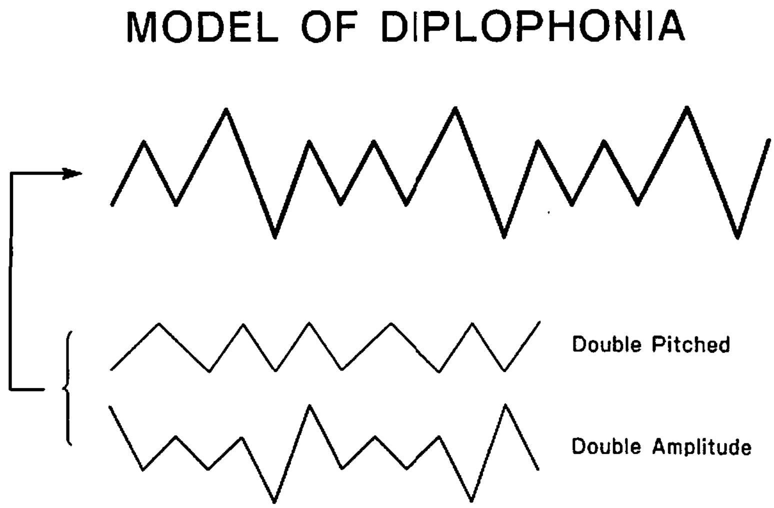

Fig. 7 A model of diplophonia

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