IMPROVING VOICE QUALITY OF HEARING-IMPAIRED BY USE OF ELECTRO-GLOTTOGRAPHIC DISPLAY

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ABSTRACT

Using an electro-glottographic device, the electro-glottogram was displayed on a cathode ray tube along with the speech sound waveform, and the possibility of utilizing the display as visual cue for laryngeal adjustment of quality of voice in the speech training of hearing-impaired was investigated. As the results of a series of trials, it was ascertained that this visual cue was useful as a feedback for modifying the mode of vibration of vocal folds. By combining this method with various others for visual display of speech, an integrated program of speech training for hearing-impaired was proposed.

INSTRUMENTAL AID FOR TRAINING VOICE QUALITY

Nowadays, various instrumental aids for visual display of speech are widely used in speech training of hearing-impaired, but they are mostly designed for the training of articulatory gestures or control of pitch and loudness of voice [1]. As for improving voice quality, there has been no training aid effectively utilized for this purpose, although it is considered to be the most basic requirement for speech intelligibility of hearing-impaired to achieve natural quality of voice.

Since it has been reported by E. Abberton and others that electro-glottography served as a visual feedback for laryngeal control in voicing [2], the possibility of applying the method to improving voice quality of hearing-impaired should be investigated.

ELECTRO-GLOTTOGRAPHY

The device used in this study was "Portable Laryngograph" which was designed according to A.J. Fourcin's principle of electro-glottography [3] and manufactured by Laryngograph Ltd. in England.

In this device, a pair of electrodes (30 milli-meters in diameter, 9 milli-meters in thickness, and weight of about 7 grams) are attached to the outer skin surface of both lateral sides of the larynx, holding by an elastic band around the neck. By applying high frequency electric current (frequency: 3 MHz, and voltage: 10 volts), the change in the current (less than 10 milli-ampare) due to the change in electrical impedance across the larynx synchronized with vibration of the vocal folds, or opening and closing of the glottis, was detected (Figure 1). The electronic circuitries including the carrier signal generator and amplitude demodulator are battery operated, so that they are insulated from the displaying and recording units. The device is small and light weighted, and easy to be handled.

The waveform of the output signal (6 volts peak to peak), the electro-glottogram, was displayed on the cathode ray tube of a synchroscope, and recorded on a data recorder in order to minimize low-frequency phase distortion.

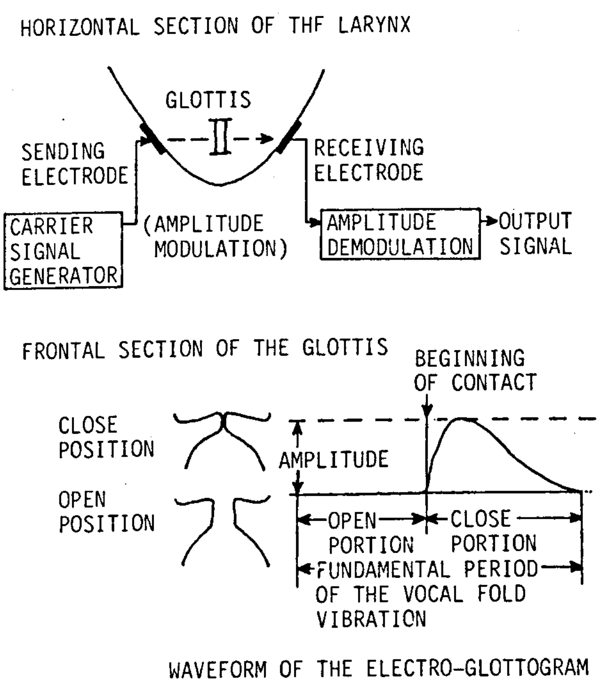

Figure 1. Description of basic components involved in the device of electro-glottography and the waveform of electro-glottogram.

For detailed inspection, the waveform of the electro-glottogram was printed out on a visi-corder along with that of speech sound recorded simultaneously, then their frequency spectrum were analyzed using a sound spectrograph.

NATURE OF WAVEFORNM OF THE ELECTRO-GLOTTOGRAM

The relationship between the vibration of the vocal folds and nature of the electro-glottogram had been investigated by the researchers on the electro-glottography through simultaneous recordings of opening and closing of the glottis observed by the fiber scope and the optical glottography, and also through modelling of the vocal fold vibration [4, 5 and 6].

Referring to their discussions, it was examined that the higher and narrower peak (or lower flat valley) in each fundamental period of the waveform of the electro-glottogram which corresponds to the tighter and shorter contact of the glottis, and the steeper rise of the curve which correspond to the quicker increase of the contact, could be used as indications of richness of the higher harmonic components of the voice source in the training of voicing (Figure 2).

The lack of the higher harmonic components in the range of lower formant frequencies results in a significant defect in the speech sound. This is one of the most difficult aspects in the articulatory training of the hearing-impaired having defective voice quality.

PROCESS OF IMPROVEMENT OF THE VOICE QUALITY

In order to find a subject for the preliminary experiment of applying the electro-glottography to the speech training as a visual feedback, firstly, eight hearing-impaired among forty (aged 19 and 20 years) who were staying in the Department of Vocational Training, Training Center of the National Rehabilitation Center for the Disabled were selected. They met the condition of; having hearing level of over 100 dB, poor speech quality, and consequently being required of integrated speech training. After analyzing their speech, a female, aged 19, who had defective voice quality but rather good articulation was chosen as the subject.

Before the training, the voice of the subject in daily conversation was abnormally high pitch and low loudness, and the tonal qulity was too soft and close to falsetto. For these reasons, the phonemic aspect of speech was not acceptable, even though her articulation was fairly good as she had had speech training in the school for the

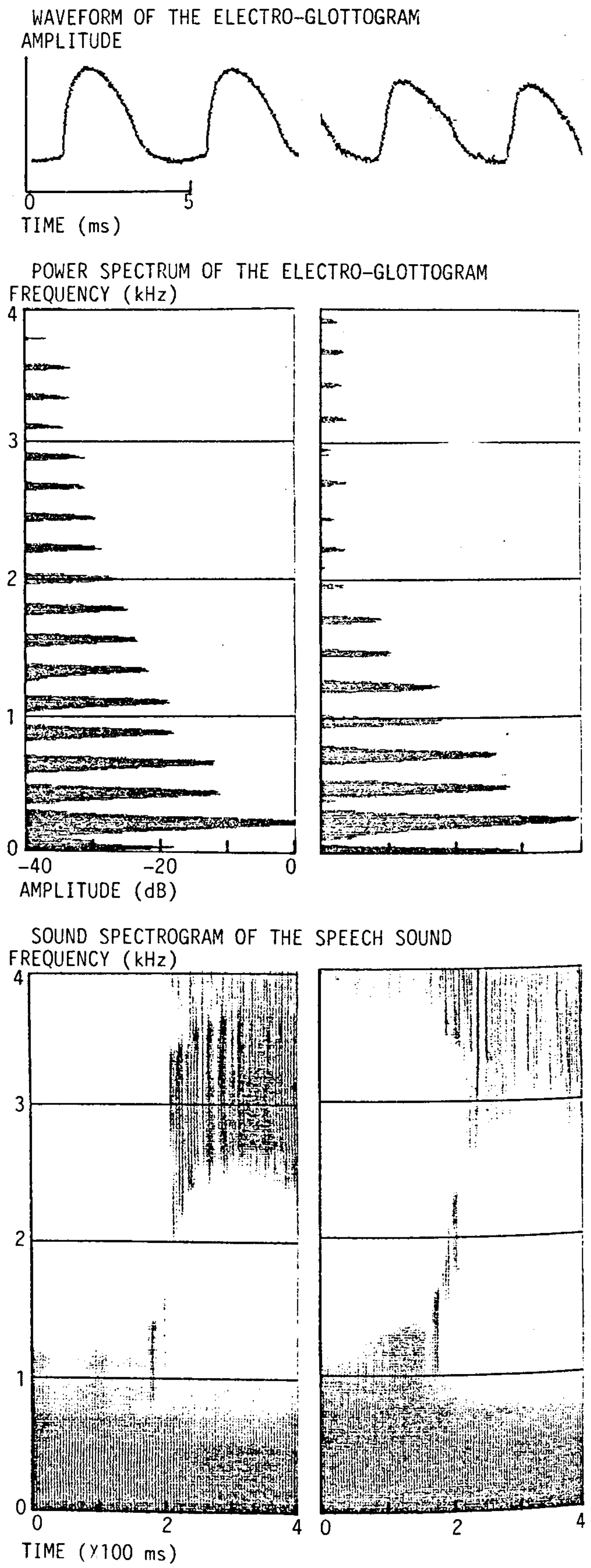

Figure 2. A pair of examples of the electro-glottograms and their power spectrums for a normal and a defective voicing, which was simulated by a female adult, and sound spectrogram of the speech sound for the utterance of Japanese vowel sequence.

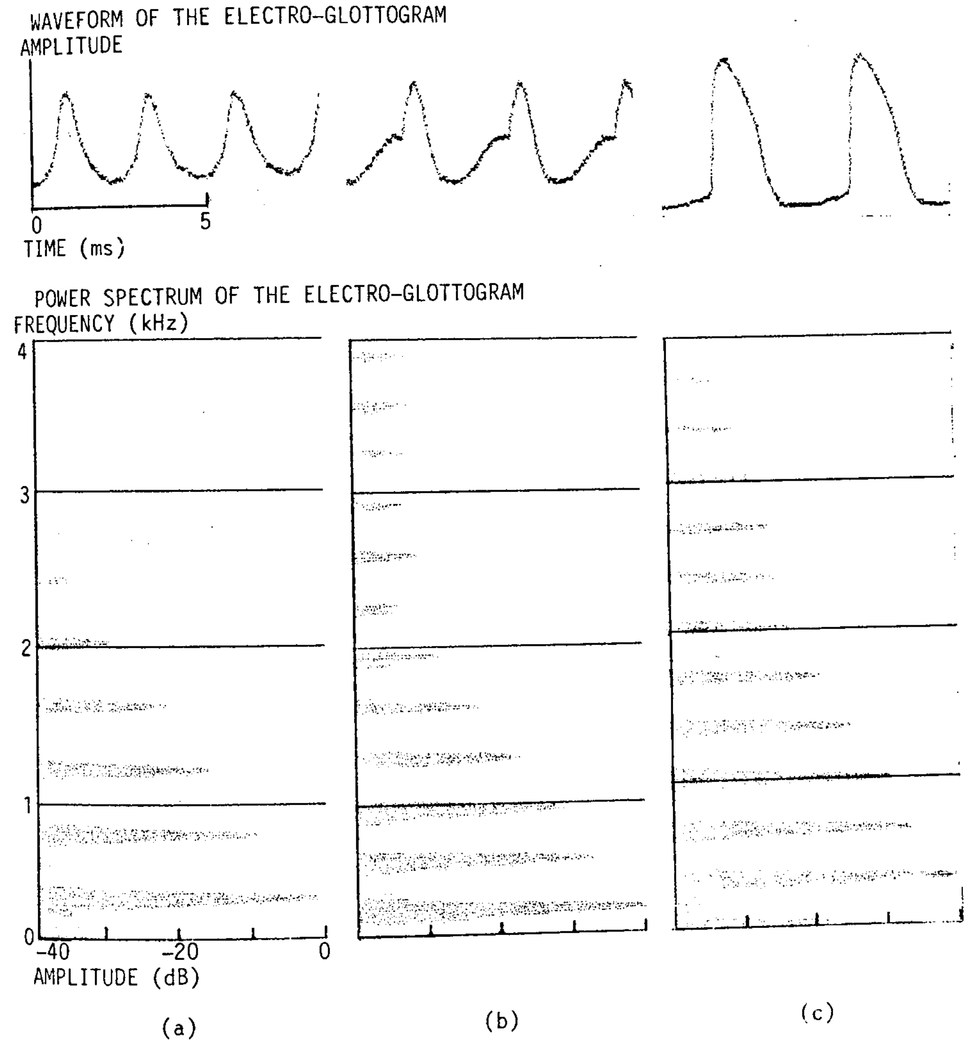

Figure 3. A set of examples of the electro-glottogram and power spectrum in the process of improvement of voice quality by the hearing-impaired subject.

deaf where she stayed for the previous twelve years. As for the prosodic aspect, the subject spoke in slow tempo with ambiguous word accent, sentence intonation and emphasis of phrase. The waveform of the electro-glottogram did not show wide flat valley or steep rise in each fundamental period, consequently, the harmonic components were found only in the low frequency range (Figure 3a). This is known as one of the common characteristics of the speech of hearing-impaired.

In the preliminary experiment of training of voicing, the subject was instructed to sustain vowel phonation by monitoring the electro-glottogram on the display, and to imitate the instructor's typical waveform especially marking steepness of the rise of the curve in each fundamental period. And the process of improvement of the quality of voice was evaluated based on the degree of richness of the higher harmonic components of the voice source through a spectrographic analysis of both the electro-glottogram and speech sound.

Soon after beginning the training, the subject was able to change the nature of the waveform of electro-glottogram by laryngeal adjustment. One way to produce a steep rize of the curve by ther subject was abnormally tensed phonation. Although the higher harmonic components became richer, the voice quality was unnatural for speech sound (Figure 3b). This is also common to the voicing of hearing-impaired, however, this needs to be checked by the tests other than the sound spectrogram.

A series of training which consisted of two sessions a week, a session being about one hour long, was conducted. After several sessions, the waveform of electro-glottogram become almost normal, resulting in the improved voice quality (Figure 3c). The fundamental frequency became lower towards normal range.

The improvement was achieved for the open vowels [o] and [a] first, but it took another several sessions to stabilize the result, and to achieve a similar improvement for other vowels, particularly for [i] which was the most difficult among the five Japanese vowels.

APPLICATION TO INTEGRATED SYSTEM OF TRAINING

In this study, it was ascertained experimentally that the hearing-impaired subject was able to adjust her voice quality through the electro-glottographic display. Parallel with this training of voice quality, a series of training for refining the articulation was conducted in sequence of vowels, semi-vowels, nasals, flapped, voiced plosives, and other Japanese consonants. Training to achieve a reasonable pitch control for such as Japanese word accent and sentence intonation began when the range of voice pitch of the subject became normal after the series of training of voice quality.

In this way, the electro-glottography for training of voice quality and various other methods for training, for control of pitch and loudness of voice through displays of changes in fundamental frequency and intensity of speech sound, and articulatory training by use of displays of lip movement [7] and lingual contact to palate [8 and 9], were assembled into an integrated program.

It is planned to combine this program of speech training with a system of objective evaluation of speech quality based on acoustical analysis [10], and to extend the range of application to hearing-impaired children in the future.

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