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 millimeters in diameter, 9 millimeters 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-ampere) 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.

HORIZONTAL SECTION OF THE LARYNX

SENDING ELECTRODE

GLOTTIS

RECEIVING ELECTRODE

CARRIER SIGNAL MODULATION)

DEMODULATION)

OUTPUT SIGNAL

FRONTAL SECTION OF THE GLOTTIS

BEGINNING OF CONTACT

CLOSE POSITION

AMPLITUDE

OPEN POSITION

OPEN PORTION

CLOSE PORTION

FUNDAMENTAL PERIOD OF THE VOCAL FOLD VIBRATION

WAVEFORM OF THE ELECTRO-GLOTTOGRAM

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 WAVEFORM 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
glottoigraphy, and also through modeling 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 frequency 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 quality was too
soft and close to falsetto. For these reasons,
the phonemic aspect of speech was not acceptable.

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-
glottograms and power spectrums in the process
of improvement of voice quality by the hearing-
impaired subject.

Improvement of the quality of voice was evaluated
largely 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 rise of
the curve by their subject was abnormally tensed
vowel 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.

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.

REFERENCES