Audio-Vocal Self Control Functions: Pitch Fluctuations and Audio-Vocal Pitch Matching

S. Eguchi and M. Suto
Tsukuba, Japan

1. Introduction

Several sensory feedback loops – auditory, tactile and kinesthetic sensations – are thought to exist for controlling voice and speech. It is well known that the auditory feedback self-control functions are the most effective among them for speech motor behavior. We can realize the importance of the auditory feedback self-control function for speech motor behavior through the fact that the voice and speech of the deaf persons have very distorted acoustical features.

This paper involves the pitch fluctuations in the sustained voices of normal-hearing and hearing-impaired children and the audio-vocal pitch matching abilities of normal-hearing adults to show the auditory feedback self-control influences upon voice production functions.

2. Experimental procedure

The pitch fluctuations of sustained voices of five Japanese vowels by normal-hearing and hearing-impaired children were measured. The subjects were 21 hearing-impaired children and 60 normal-hearing children of 7 to 12 years old. Voice samples for 3-5 seconds were recorded. Each 200 ms of the onset and offset periods of voices was eliminated because voice pitch of these portions was not stable. Fundamental frequencies were measured at 100 ms measurement points in the stable portions of the analog output with a pitch meter and the results were shown in the Figures 1, 2 and Table I.

The relative pitch fluctuations to the mean fundamental frequencies (SD/F_0) of hearing- impaired children's voices (0.93%-3.10%) showed clearly higher values than those of normally hearing children (0.49% – 0.89%). The correlation of age with relative pitch fluctuations of hearing-impaired children was not pronounced but that of hearing threshold at the lower frequencies (250Hz and 500 Hz) with relative pitch fluctuations was manifest.

The audio-vocal pitch matching by normally hearing adults was examined.

The subjects were 5 normally hearing male adults without special musical training.

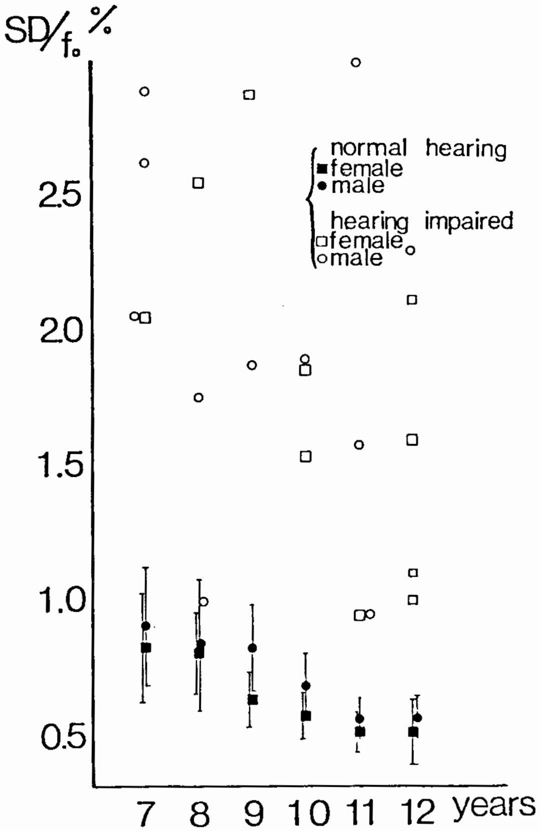


Figure 1. Relative Pitch Fluctuation as a Function of age.

130 Hz and 145 Hz tones were used as the base voice pitch for each subject to produce a natural sustained voice. The test target tone generated by an oscillator was given to the right ear of subjects at 45 dB HL through a headphone (TDH-49) and subjects produced the Japanese vowel /a/ at a pitch as near as possible to that of the target tone. When the sustained voice of a subject had been continued for about 2 seconds, the pitch of the target tone was changed higher or lower by 10 Hz or 20 Hz. Subjects perceived the pitch changes of target tones and then followed the changed pitch of target tones matching their own voice pitch with the pitch of target tones. The speech samples and target tones were recorded on a 2 channel tape recorder at the same time and their pitch was extracted by a 2 channel pitch meter and recorded on an analog display.

To measure the subjects' audio-vocal pitch matching abilities, three temporal time lags – from the beginning of the pitch change of a target tone to the beginning of the pitch change of the subjects' voice, from the beginning of the pitch change of a target tone to the end of the pitch change of the subject's voice, and from the beginning of the pitch change of a target tone to stabilizing of the subject's sustained voice – were obtained and the results are shown in Figure 3 and Table II.

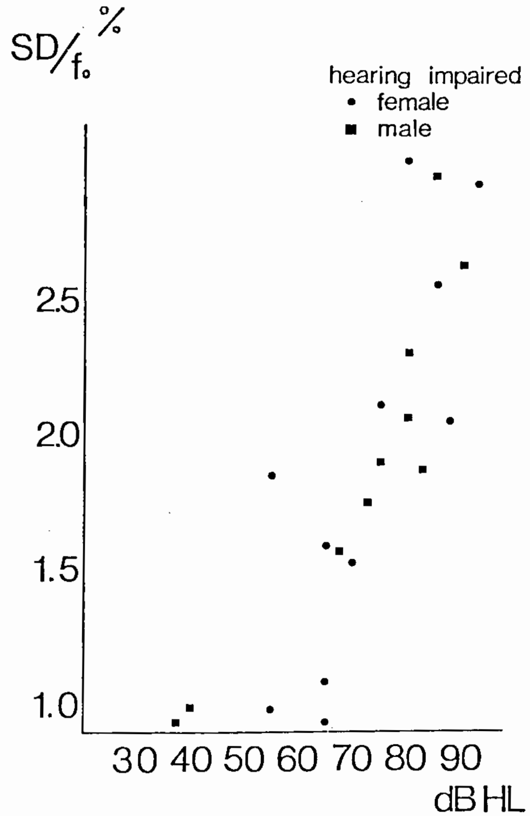


Figure 2. Relative Pitch Fluctuation as a Function of Hearing Threshold.

3. Results

The time lag from the beginning of the pitch change of a target tone to the beginning of the pitch change of the subject's voice ranged from 328 ms to 405 ms. The mean value of this time lag was 351 ms, the between-subject standard deviation in the distribution of this time lag was 82 ms, and the intra-subject standard deviation was 75 ms. There was no significant difference in the data of the time lags among the four conditions in which pitch changes of target tones were different.

The time lag from the beginning of the pitch change of a target tone to the end of the pitch change of the subject's voice ranged from 674 ms to 830 ms. The mean value of this time lag was 756 ms, the between-subject standard deviation in the distribution of time lag was 181 ms and the intra-subject

Table I.

Normal hearing (N = 60)

Age	Male SD/F (%)	Female SD/F (%)
7	0.89	0.81
8	0.82	0.79
9	0.81	0.63
10	0.67	0.58
11	0.56	0.50
12	0.56	0.49

Hearing-impaired (N = 21) HL: (250 + 500 Hz)/2

Age	Male HL (dB)	SD/F (%)	Age	Female HL (dB)	SD/F (%)
7	80	2.05	7	87.5	2.04
7	85	2.95	8	85	2.54
7	90	2.61	9	92.5	2.91
8	40	0.99	10	55	1.84
8	72.5	1.74	10	70	1.84
9	82.5	1.86	11	65	0.93
10	75	1.88	12	65	1.58
11	80	3.10	12	55	0.98
11	67.5	1.56	12	75	2.10
11	37.5	0.93	12	65	1.08
12	80	2.29			

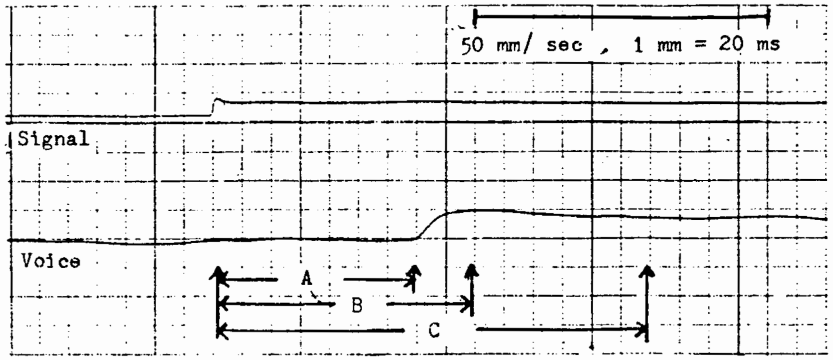
Table II. Latencies for the signal change

	Onset	End	Stable stage
Mean	351.5	756.9	1326.2 msec.
B.S.S.D.	82.9	181.3	325.6
I.S.S.D.	75.9	115.9	245.6

B.S.S.D.: Between subject standard deviation; I.S.S.D.: Intra subject standard deviation.

standard deviation was 115 ms. When the pitch of a target tone was changed to lower pitch, the time lag was shortened significantly in comparison with the condition in which the pitch of the a target tone was changed to a higher pitch.

The time lag from the beginning of the pitch change of a target tone to the stabilizing of the subject's sustained voice ranged from 1226 to 1409 ms. The mean value of this time lag was 1326 ms, the between-subject standard deviation in the distribution of this time lag was 329 ms and the intra-subject standard deviation was 245 ms. There was no significant difference in the data of the time lags among the four conditions in which pitch changes of target tones were different.



A: Latency to the onset of voice inflection
B: Latency to the end of voice inflection
C: Latency to the stable stage of sustained voice

Figure 3. A Sample of Actual Recording.

4. Conclusion

From our present experimental results concerned with the influence of the auditory self control functions on voice and speech behavior which are very important for the development of speech sounds in early childhood, it was shown that the fluctuations of sustained voice were not correlated with age but with hearing thresholds and that there were several time lags between auditory target tone and the achievement of voice responses in the audio-vocal pitch matching ability.

References

Chase, R.A. and Guilforyle, G. (1962). The effect of simultaneous delayed and undelayed auditory feedback on speech. *Journ. of Speech and Hearing Research,* **5**, 144-151.

Eguchi, S. and Hirsh, I.J. (1969). Development of speech sound in children. *Acta Otolaryng, Suppl.* 257.

Monsen, R.B. (1979). Acoustic qualities of phonation in hearing impaired children. *J. Acous. Soc. Amer.* **22**, 270-288.