POSSIBILITIES OF COMPENSATION IN SPEECH PRODUCTION

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ABSTRACT

Possibilities of compensation in speech production are discussed from viewpoints of control of speech organs, realization of acoustical requirements and role of the auditory feedback, taking examples of lip, tongue and jaw movements for the vowel and consonant utterances by normal adults and children and by hearing-impaired children.

1. ASPECTS OF COMPENSATION

It has been widely noticed by researchers in their observations on speech production process that gestures of phonation and articulation can be substituted in various ways in order to compensate for personal deviation in speech organs in normal cases, and especially for their defects in pathological cases.

In this report, aspects of the possibilities of compensation in speech production are discussed with regard to whether the control of speech organs is arbitrary or not, how far the acoustical requirements are realized, and what kind of role the auditory feedback plays.

Examples used here are lip spreading and rounding, lingual contact to the palate and muscle contraction in articulator for vowels and consonants by normal adults and children having different shape and size of the palates, and by hearing-impaired children with normal articulator.

2. ARBITRARY CONTROLS OF THE LIPS

On the three-dimensional matrix consisted of axes of the front and back movements of tongue, the high and low displacements of the tongue, and spreading and rounding of the lips, the five Japanese vowels [i, e, a, o, u] can be represented as shown in the top left of Fig. 1. The characteristic shapes of the mouth basically correspond to the second and third axes (bottom right) rather than to the first and second axes (bottom left). In order to coordinate the configuration and the data of stroboscopic observation of the mouth shape [1], the jaw opening (displacement of the lower incisors) and the separation and width of the lips are also shown in the bottom right.

As the area of the lip opening is nearly proportional to the product of the width and separation of the lips, they can be traded each other for keeping the area required by each kind of vowel (along the bold lines).

This is an aspect of the compensation in speech production in which suitable gesture within acceptable range for each vowel has been arbitrary chosen by each speaker in the development of articulation.

3. CONSTRAINTS BY PALATE SHAPE

3.1. Difference in Palate Shape

Fig. 2 shows the boundary of the area of the maximum lingual contact to the hard palate in the monosyllabic utterance of [i] in solid line by two adult subjects as examples. They were extracted through the frame-by-frame inspection of the recorded electro-palatograms (with sixty-four electrodes), and drawn on the photograph of the frontal view of the plaster cast of the palate of each subject covered with the artificial one [2].

The palate of the left subject was wider and deeper, and the boundary of the contact for [i] was closer to the mid-sagittal plane, while the boundary of the right subject was near the lateral edge of the palate.

In this aspect of compensation, lingual contact has been involuntary adjusted to peronal difference of the palate shape through auditory feedback, in order to realize the acoustical requirement for the vowel.

3.2. Growth of Child Palate

Reference lines were drawn on the horizontal and vertical views of the plaster casts of the hard palates of the fifteen adults (M: male, F: female), thirty children in the dental stages; IIA, C, IIIA, B, C and IVA, and two children (a: boy, b: girl) in different dental stages, as shown in the top of Fig. 3, and used for the measurement of the size of various parts of the hard palate [3]. The size and shape of the hard palate changes significantly as the subject grows, as shown in the bottom. The shape of palate in children has the characteristic that the front part is shorter and shallower compared with that of an adult. Consequently, the surface of the tongue tip is apt to contact a wider area of the front of the hard palate.

Examples of the area of maximum lingual contact at the closure of alveolar flapped [r] are shown in the left column of Fig. 4, and alveo-dental plosives [d] in the right column. The utterance by one of the child subjects is shown in the bottom row, while that of one of the adult subjects in the top. In the utterance by children, the area of maximum contact at the closure of such consonants tends to be closer to the front edge of the hard palate, compared with the adult subject, and does not show the characteristic pattern for each consonantsas compared with the adult subject.

In this aspect, constraints by the palate shape are too strong to be compensated, even though those consonants may be perceptually differenciated each other by normal children and acoustical target for each may be settled in a higher level of motor control.

4. DEFECTS IN AUDITORY FEEDBACK

Measurement of the formant frequencies of the five Japanese vowels uttered by forty-two hearing-impaired children [4] showed that the vowel-space deviated in various way from that of the normal children. They can be classified into the following types; the shape similar to that of the normal children but the range of F2 reduced slightly, the range of F2 reduced and the pentagonal shape rotated, the range of F2 also reduced and [a] and [o] came closer to each other, the range of F2 reduced and [i] and [e] came closer to each other, both F1 and F2 almost neutralized, and the range of F2 reduced and F1 raised, as shown in the left of Fig. 5.

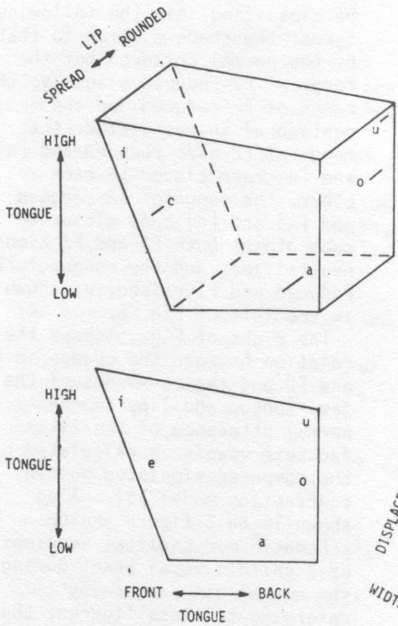
The right of Fig. 5 shows the relation between the change in F1 and F2 and the movements of the jaw, tongue and lips in the normal utterance of the five Japanese vowels as calculated by the computer-simulated muscle contraction model [5]. Also shown in this figure are the schematic mid-sagittal sections of a child's vocal tract during the normal utterance. By referring to these figures, the deviation of the vowel-space of hearing-impaired children from those to the normal children can be explained in terms of the nature of the imperfection of articulatory movement.

The reduction of the range of F2 implies that the forward pull of the tongue for [i] and [e] and the backward pull for [o] and [a] were not sufficient. The deviation of F1 and F2 of [i] toward the normal area of [e] shows that the constriction of the vocal tract was not narrow enough, while that of [o] toward the normal area of [a] suggests that the protrusion of the lips for [o] was not sufficient.

Those deviations of the vowel-space of the hearing-impaired children having basically normal articulator were due to the defects in auditory feedback which is indispensable for the compensation in speech production. Therefore, analysis on how the vowels were contrasted with each other in vowel-space, along with the considerations on the range of arbitrary controls and constraints in articulator for realization of the acoustical requirements, will provide a useful data for the basic nature of compensation in articulation.

5. REFERENCES

[1] Fukuda, Y. and S. Hiki(1982), Characteristics of the mouth shape in the production of Japanese: Stroboscopic observation," J. Acoust. Soc. Japan (E), 3(2), 75-91.
[2] Hiki, S. and H. Itoh (1986), "Influence of palate shape on lingual articulation," Speech Communication, 5, 141-158.
[3] Hiki, S. and R. Kagami(1976), "Some properties of formant frequencies of vowels uttered by hearing-impaired children," J. Acoust. Soc. Amer., 59(S1), S86.
[4] Hiki, S. and J. Oizumi(1974), "Speech synthesis by rule from neurophysiological paramerter," Preprints, Speech Communication Seminar, Stockholm, 219-225.



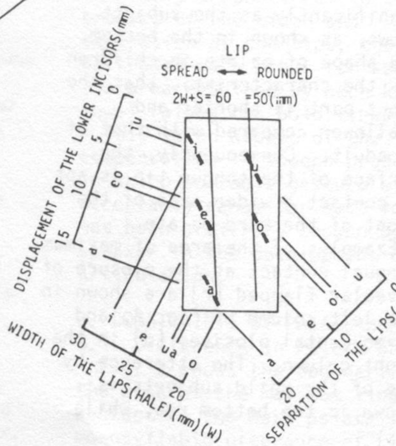
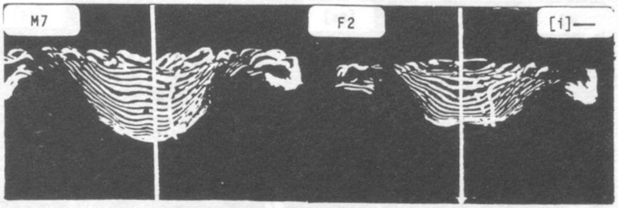
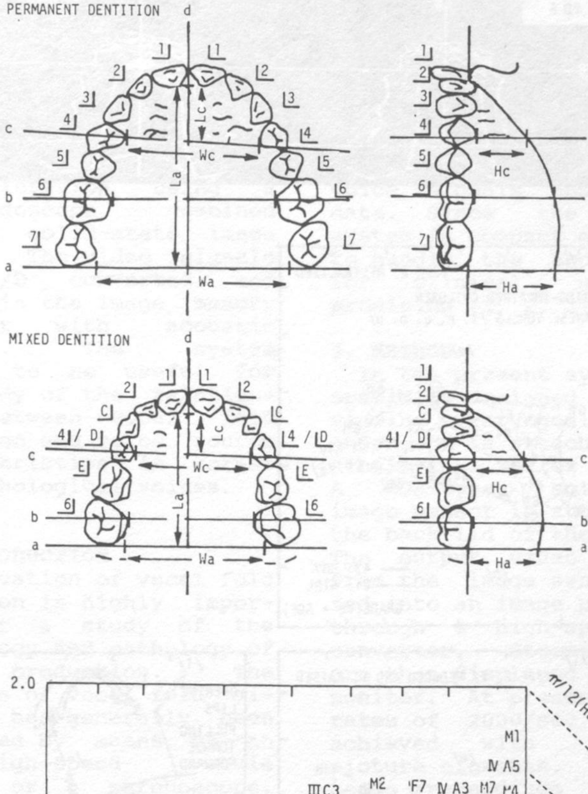


Fig. 1.

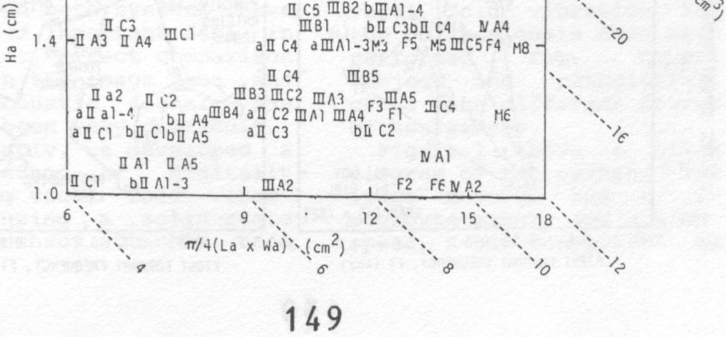


M7
F2
[i]—

Fig. 2.



PERMANENT DENTITION
MIXED DENTITION
d
a
b
c
a'
b'
c'
La
Lc
Wa
Wc
Ha
Hc



Ha (cm)
2.0
1.4
1.0
6
9
12
15
18
π/4(La x Wa) (cm²)
π/12(Ha x La x Wa) (cm³)
24
20
16
12
10
8
6
4
M1
M2
M4
M5
M6
M7
M8
M3
F1
F2
F3
F4
F5
F6
F7

Fig. 3.

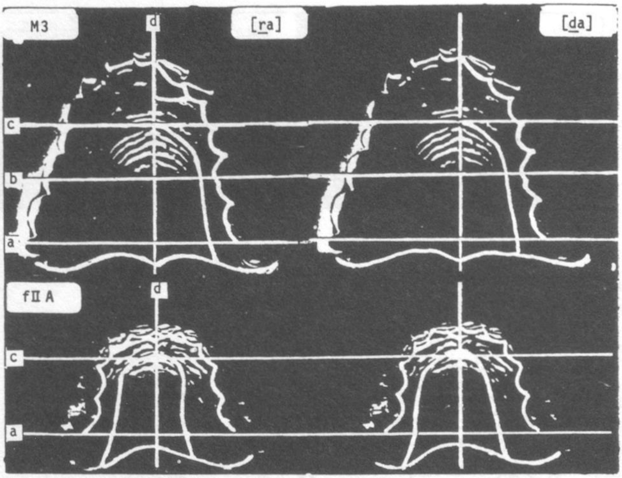

M3
[ra]
[da]
d
c
b
a
fII A

Fig. 4.

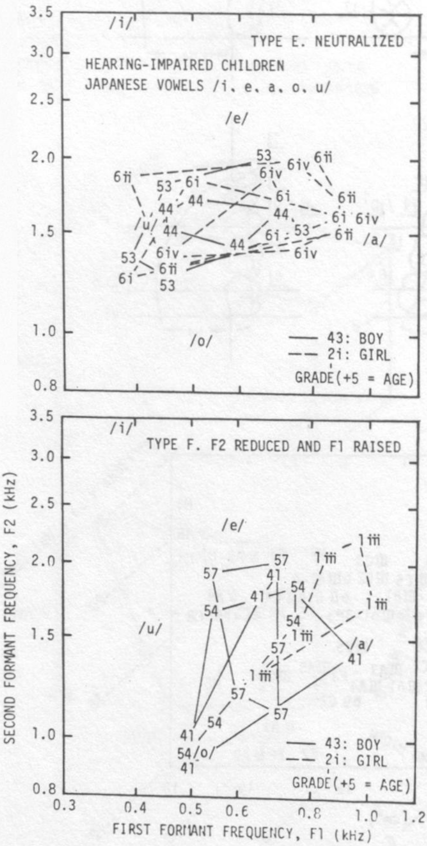
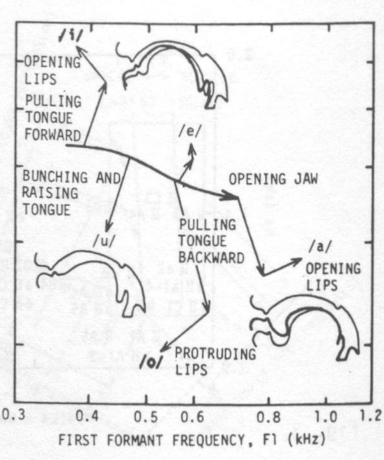

TYPE E. NEUTRALIZED
HEARING-IMPAIRED CHILDREN
JAPANESE VOWELS /i, e, a, o, u/
/i/
/e/
/u/
/a/
/o/
43: BOY
2i: GIRL
GRADE(+5 = AGE)
TYPE F. F2 REDUCED AND F1 RAISED
SECOND FORMANT FREQUENCY, F2 (kHz)
FIRST FORMANT FREQUENCY, F1 (kHz)

Fig. 5.


/i/
OPENING LIPS
PULLING TONGUE FORWARD
BUNCHING AND RAISING TONGUE
/e/
OPENING JAW
/u/
PULLING TONGUE BACKWARD
/a/
OPENING LIPS
/o/
PROTRUDING LIPS
FIRST FORMANT FREQUENCY, F1 (kHz)