# Changes of Vocal Tract Shape and Area Function by F0 Shift

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## Abstract

Articulatory variation due to the production of vowels at five pitch frequency (F0) levels (110 Hz, 123 Hz, 130 Hz, 146 Hz, and 164 Hz) was analyzed by volumetric magnetic resonance imaging (MRI). Three Japanese male subjects produced sustained Japanese vowels /a/ and /i/. Observation of vocal tract area functions extracted from the MRI data revealed that F0 shift in vowel production affects not only the length of the vocal tract but also its shape. Analysis employing coefficient of variation for length-normalized area functions revealed that the shape of the vocal tract does not change proportionately by F0 shift and that each subject adopt different strategies for controlling F0 while maintaining the phonetic identity of the vowel.

## 1. Aims

- To explore possible effects of F0 shift on vocal tract shape.
  - Differences of effects on vocal tract shape among vowels.
  - Differences of strategies to control F0 preserving vowel characteristics among speakers.
- To investigate acoustic effects of the changes of vocal tract shape with F0 change.

## 2. Volumetric MRI Data Acquisition

- Subject: three Japanese males (subject A, B, and C)
- Vowel: Japanese vowels /a/ and /i/

- The subjects put on intra-aural headphones.
- Harmonic complex tones were present during scanning.
  - Fundamental frequency: 110, 123, 130, 146, 164 Hz.
- The subjects were instructed to adjust their F0 to the fundamental frequency of the tone.
- Subject's voice was recorded and examined to confirm whether they adjusted their F0 as instructed.

*Optical microphone (phone-or FOMRI)*

## 3. Morphological Analysis

- Subjects A and B: the larynx tended to rise with rising F0.
- Subject C: the laryngeal cavity expanded with rising F0.

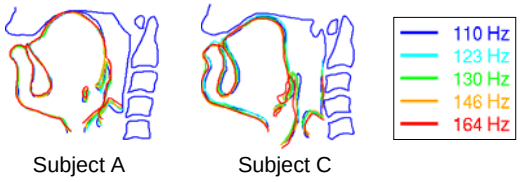



*Fig. 1. Superimposed mid-sagittal tracings for the vowel /i/.*

*Table 1. Vocal tract length [cm] associated with F0 and correlation coefficient r between them.*

| F0 | Subject A | | Subject B | | Subject C | |
|---|---|---|---|---|---|---|
| | /a/ | /i/ | /a/ | /i/ | /a/ | /i/ |
| 110 Hz | 16.6 | 16.8 | --- | --- | 17.2 | 16.0 |
| 123 Hz | 16.4 | 16.7 | 17.3 | 16.1 | 17.6 | 16.2 |
| 130 Hz | 16.4 | 16.7 | 17.1 | 16.1 | 17.6 | 16.0 |
| 146 Hz | 16.2 | 16.6 | 16.8 | 15.8 | 17.2 | 15.8 |
| 164 Hz | 16.0 | 16.2 | 16.5 | 15.7 | 17.4 | 16.3 |
| *r* | -0.99 | -0.93 | -1.00 | -0.96 | -0.04 | 0.26 |

Strong negative correlations

## 4. Analysis of Vocal Tract Area Function

Cross-sectional areas along the mid-line of the vocal tract were extracted at 2.5-mm intervals from the MRI data set.

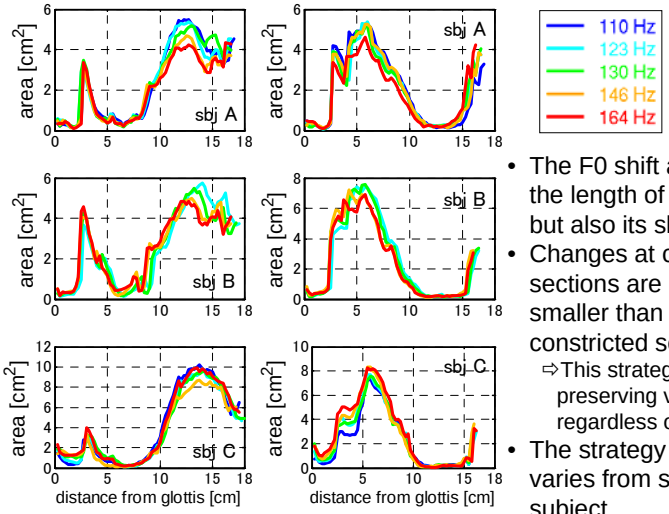
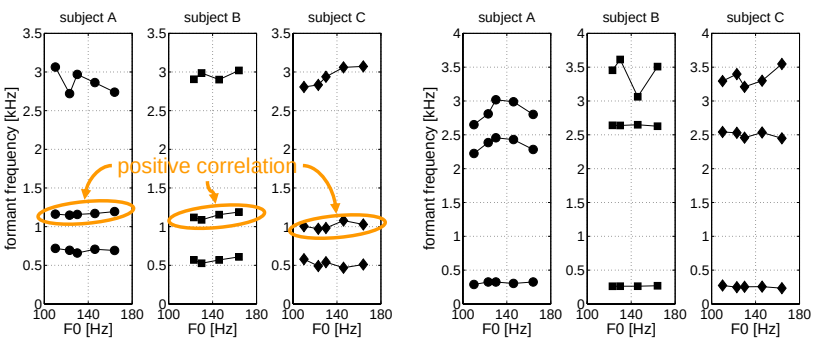



*Fig. 2. Vocal tract area functions at all F0 levels for the vowels /a/ and /i/ of the three subjects.*

- The F0 shift affects not only the length of the vocal tract but also its shape.
- Changes at constricted sections are relatively smaller than those at non-constricted sections.
  - ⇨This strategy contributes to preserving vowel features regardless of the F0 level.
- The strategy to control F0 varies from subject to subject.
  - The lower pharyngeal and laryngeal cavities of subject C varied widely.

## 5. Simulation using transmission line model

The first three formant frequencies of the transfer functions of the area functions were calculated by using a transmission line model.




(a) Vowel /a/ (b) Vowel /i/

*Fig. 3. F1, F2, and F3 of velocity-to-velocity transfer functions.*

## 6. Conclusions

Volumetric MRI was used to investigate changes in vocal tract configuration during vowel production by F0 changes.

1. F0 shift affects not only the length of the vocal tract but also its shape.
2. The strategy for controlling F0 preserving vowel characteristics differs across individuals.
3. The shape of the vocal tract changes non-uniformly with F0.
4. The regions of changes are different among vowel types and subjects.
5. The simulation results indicated that the vowel /a/ tends to neutralized with F0 rising.

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