Contributions of the Piriform Fossa of Female Speakers to Vowel Spectra

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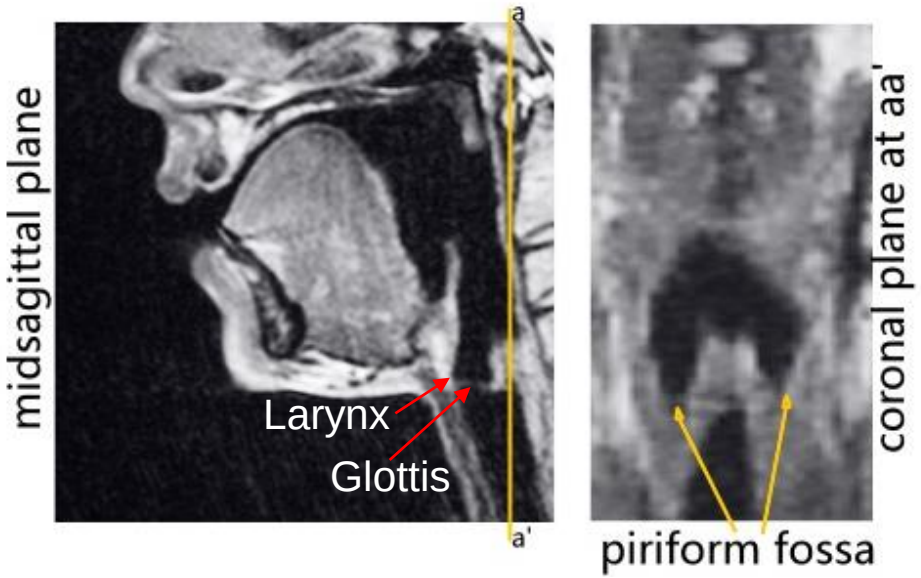
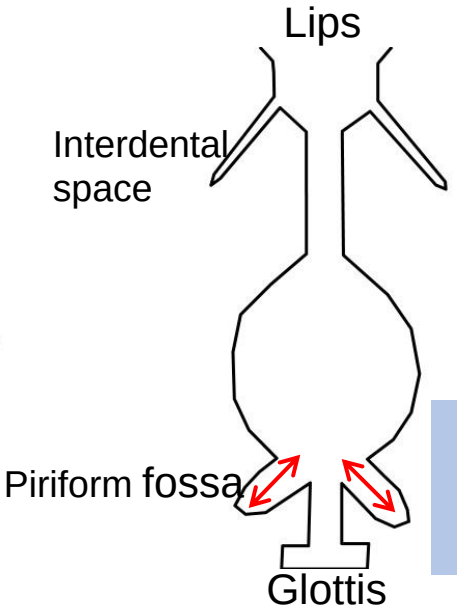
Introduction

- **Background**

  - The piriform fossa is a part of the vocal tract located near the larynx.
  - It offers anti-resonance to vowel spectra as a paired side branch of the vocal tract.





Anti-resonance: Energy absorption by the side branch

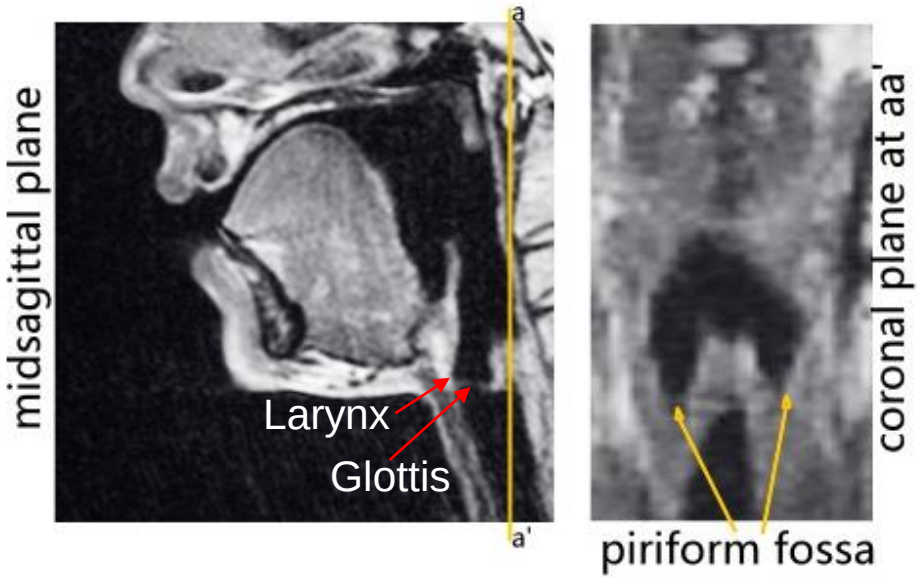
Introduction

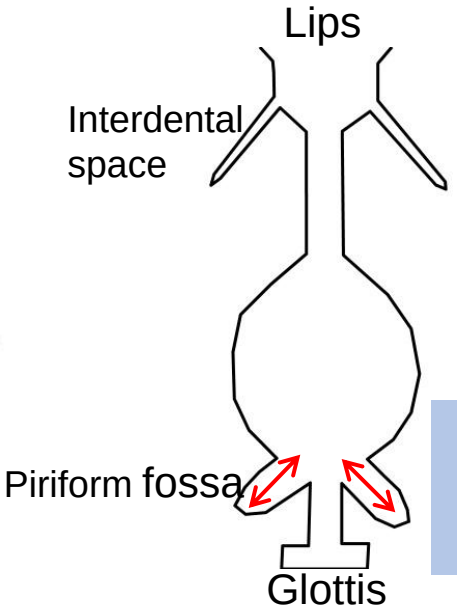
- **Background**

Role of the piriform fossa

➢Contributes to expressing individual vocal characteristics.

➢Helps adjust voice quality by cavity deformation.





Anti-resonance: Energy absorption by the side branch

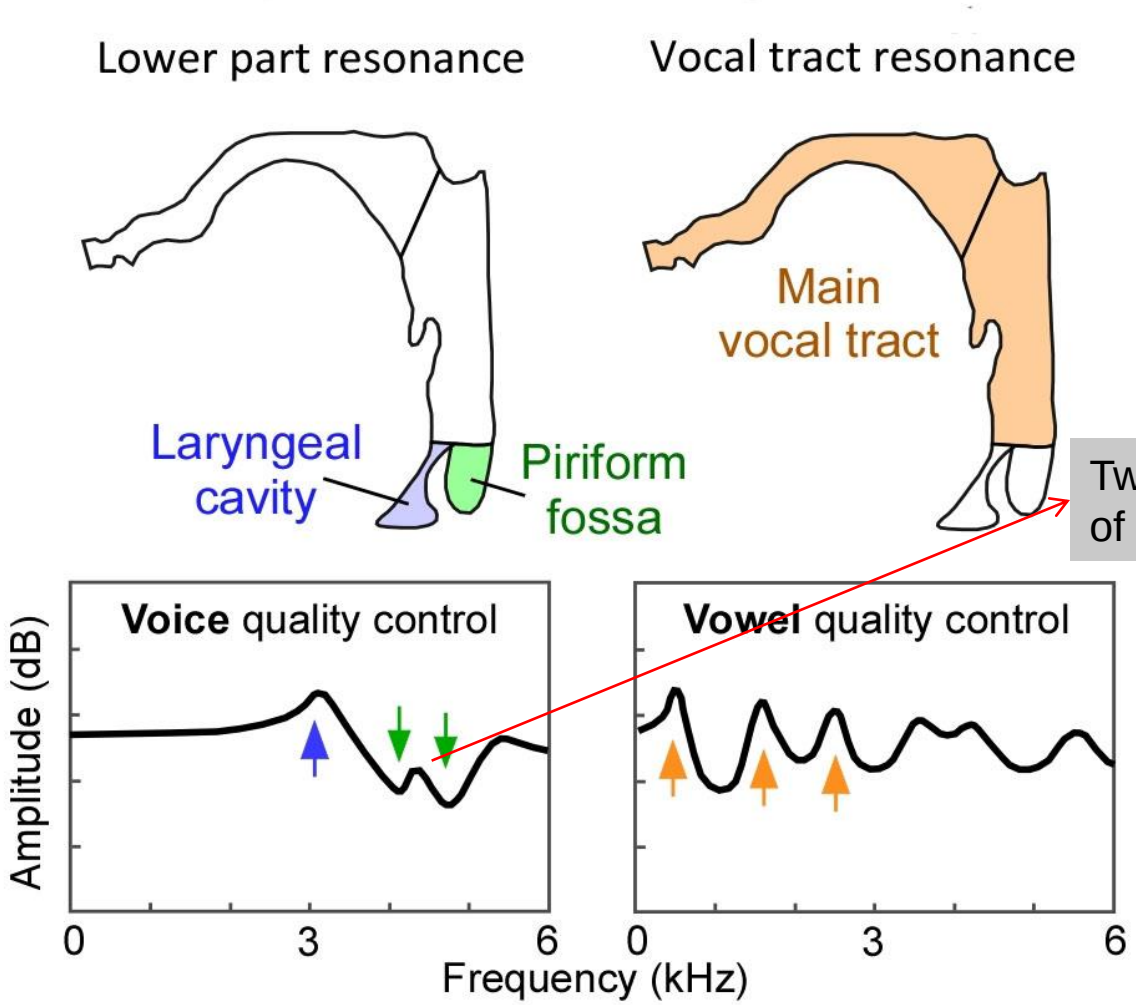
Literature review

1. **Dang & Honda (1997)** investigated acoustic characteristics of the piriform fossa by employing the water-filling method in human experiment.
   - The piriform fossa generates anti-resonance in the narrow frequency region (4-5 kHz).

2. **Honda, et al. (2010)** built male and female vocal-tract models using MRI data and analyzed the effect of the piriform fossa on vowel spectra.
   - The female piriform fossa causes acoustic effects in the wider frequency range. Whether this is a general observation or not is uncertain.

Resonance of the lower and main parts of the vocal tract

(Honda, et al., 2010)



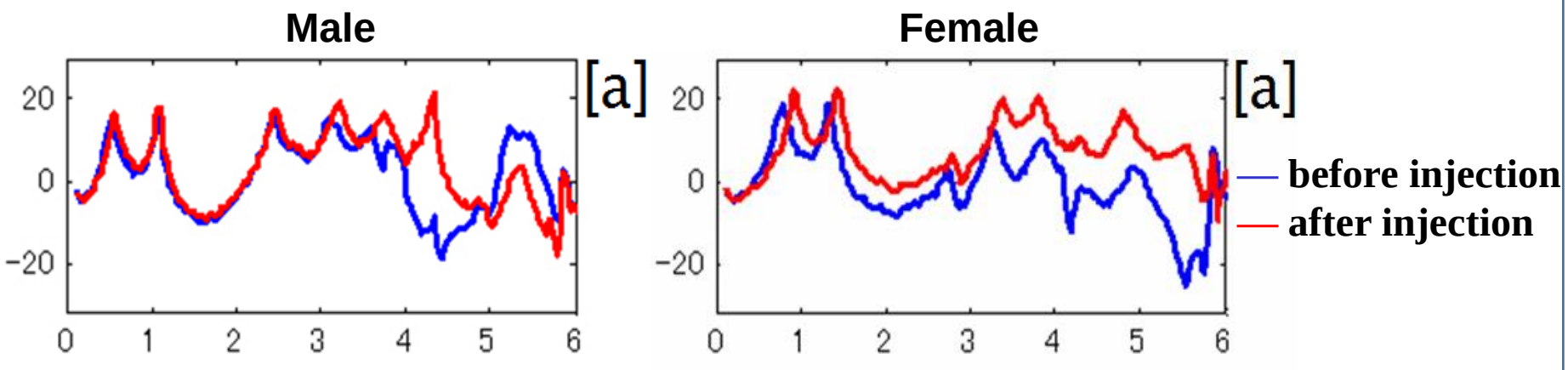
Back view of the male and female vocal tract models in the water-filling experiment

(Honda, et al., 2010)

male **female**

Male and female spectra with and without the piriform fossa in water-filling experiment in vowel */a/*

(Honda, et al., 2010)

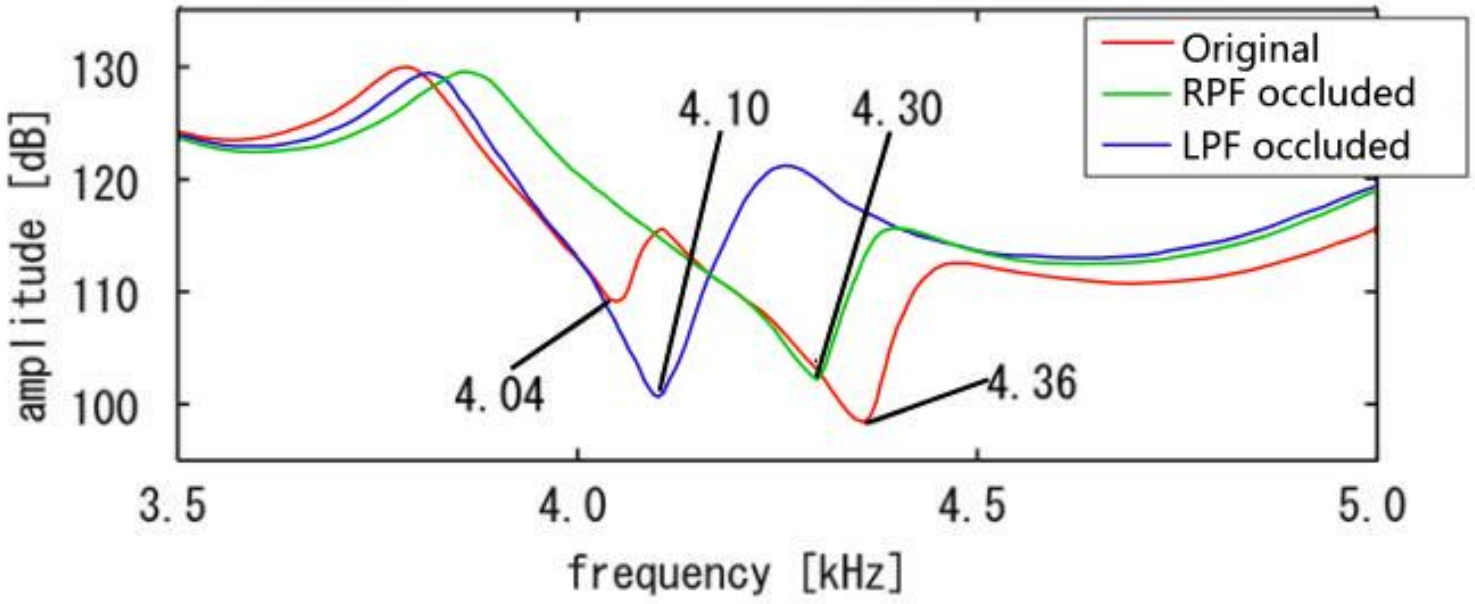


- Male piriform fossa causes a regional effect above 4 kHz, while the female fossa generates the wider spectral change.
- The female's fossa has the greater effect on vocal-tract resonance.

Literature review

3. **Takemoto, et al. (2013)** investigated acoustic interaction between the left and right piriform fossa using the finite-difference-time-domain (FDTD) method.

A new anti-resonance appears when one side is occluded.



Research Purpose

- **Purpose to re-examine female piriform fossa**

1. To explore acoustic contributions of female piriform fossa to vowel spectra.
2. To examine acoustic interaction between the left and right cavities of the piriform fossa.

To do so, **acoustic experiment** was conducted on **three female vocal-tract models.**

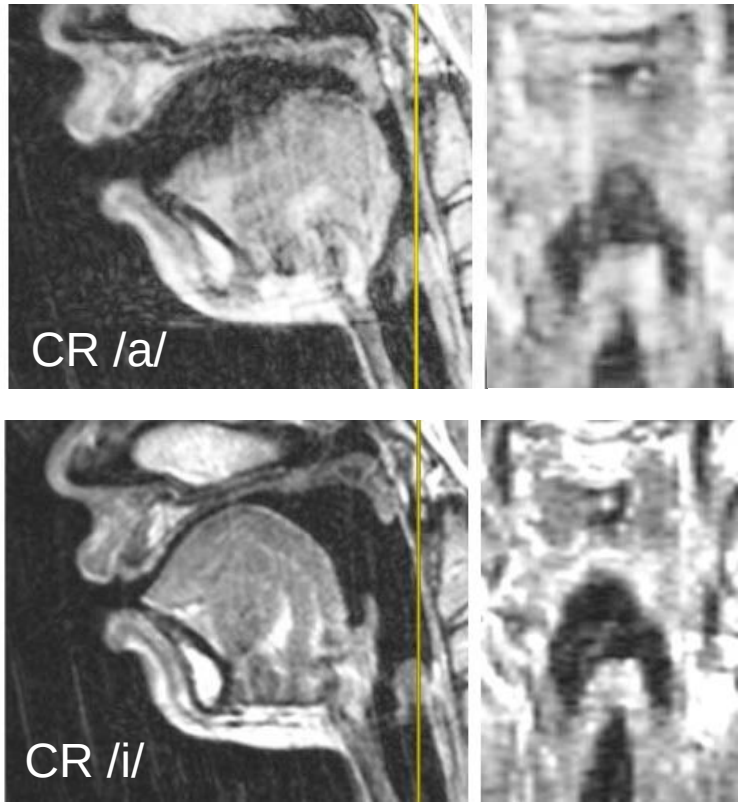
Materials and MRI data

◆Subjects

- Three female and one male speakers of Chinese.
  - Female subject: CR, LH and SC
  - Male subject: WS (as a control)

◆MRI Data

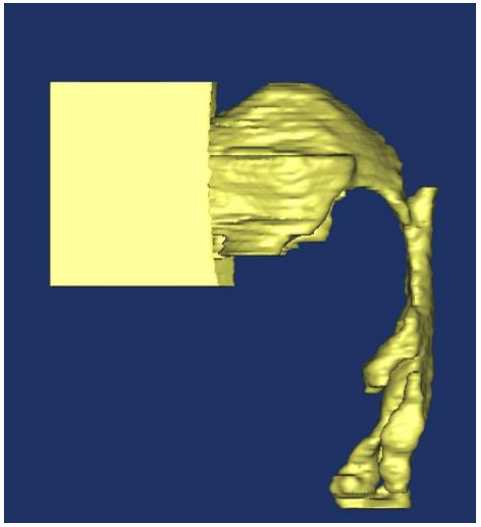
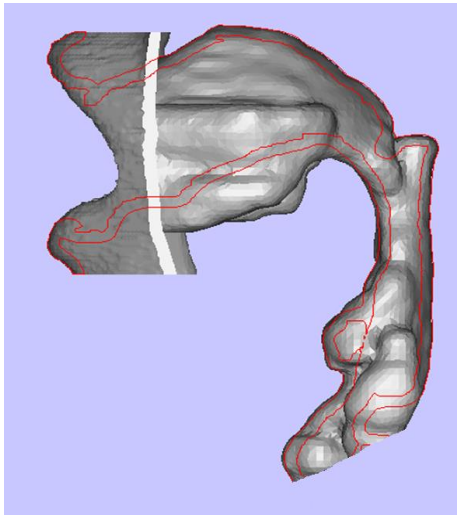
- MRI vowel data
  - Synchronized scan
  - Vowels: /a/ and /i/
  - 2.0-mm slice thickness
- MRI teeth data
  - Static scan
  - 1.0-mm slice thickness



Procedure to build 3D vocal-tract models

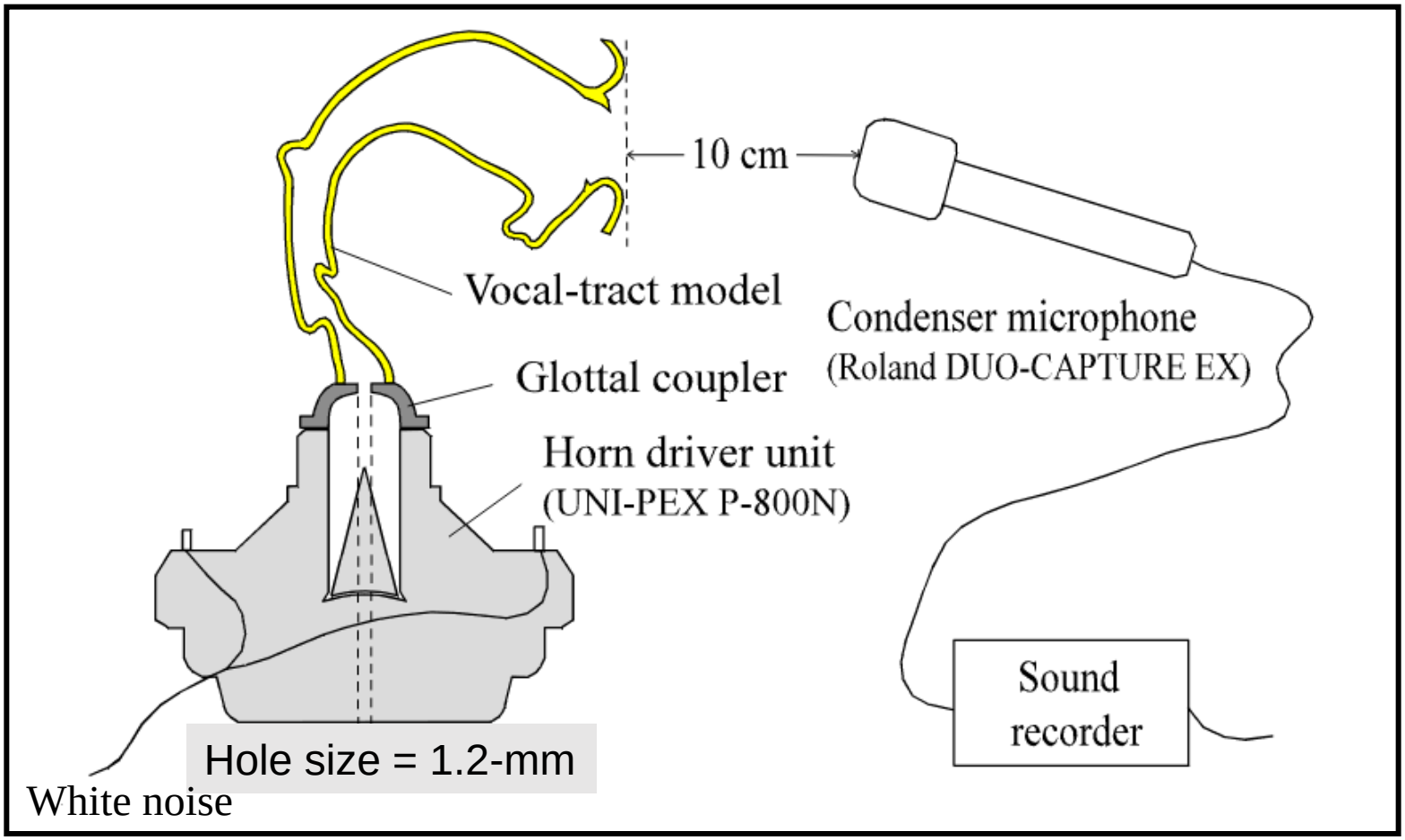
- **Extract vocal-tract shapes from MRI data**
- **Convert the extracted volunme into STL formant**
- **Build a 3-mm wall outside the vocal-tract region**
- **Print 3D vocal-tract models**

- Software: MATLAB, Mimics.
- Device: Formlabs laser printer (0.05-mm resolution).


Experiment

Setup for acoustic experiment on the models

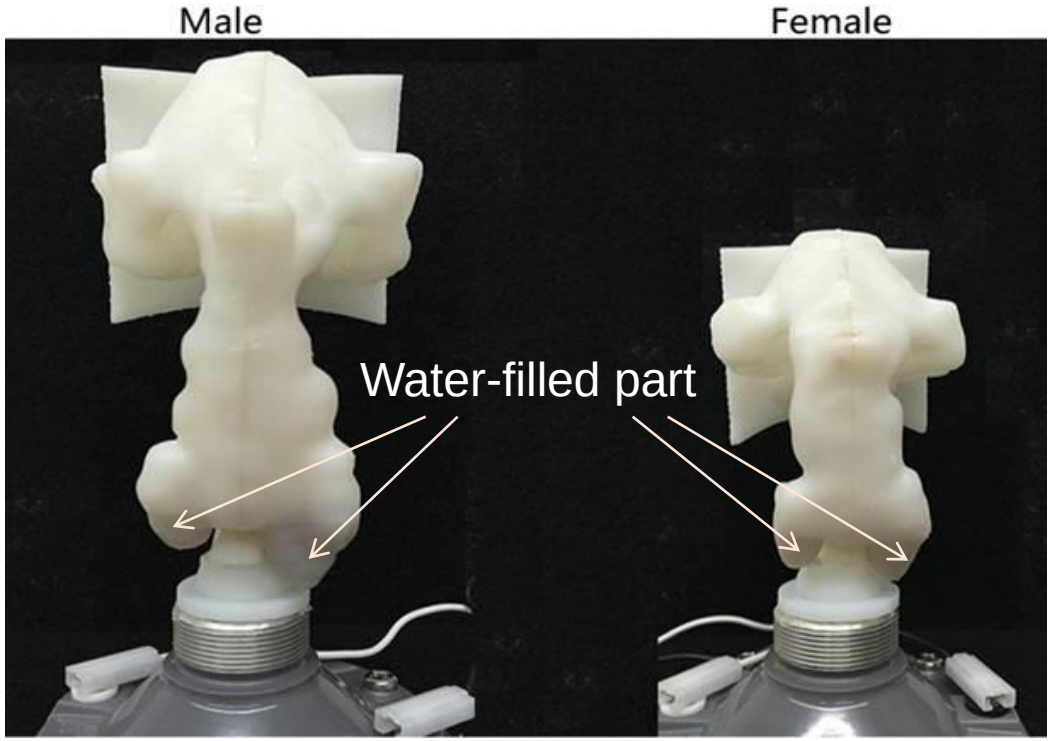


- **Record sound signals from vocal tracts** by a condenser microphone.
- Keep **10-cm distance** from the lips to the microphone.

Experiment

Acoustic recording was performed under the following four conditions:

- **NF:** Both cavities open (natural condition)
- **LF:** Left cavity filled
- **RF:** Right cavity filled
- **BF:** Both cavities filled



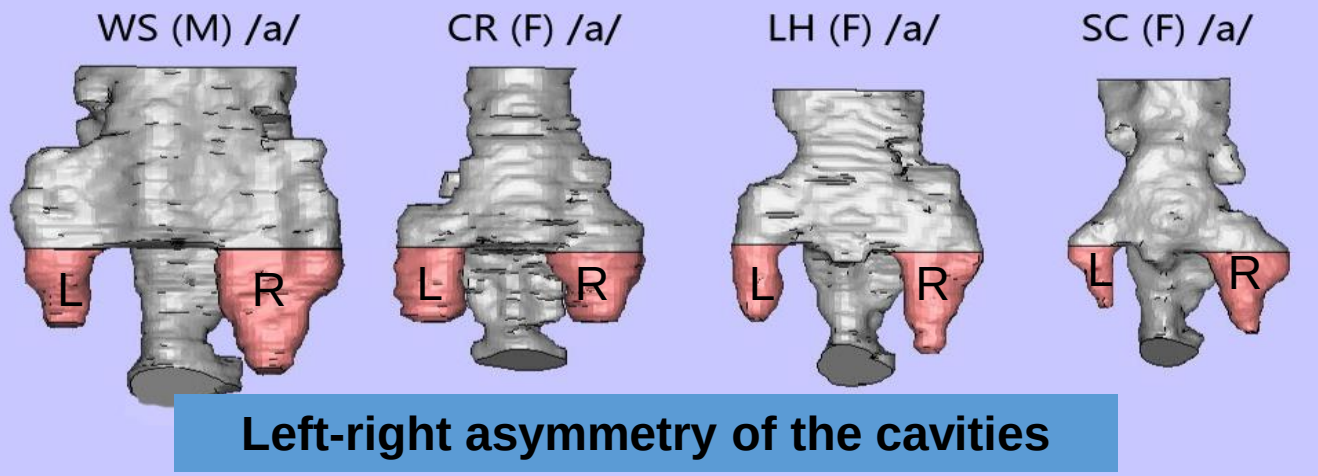
Acoustic Analysis

- Cepstral analysis
- Noise spectrum subtraction

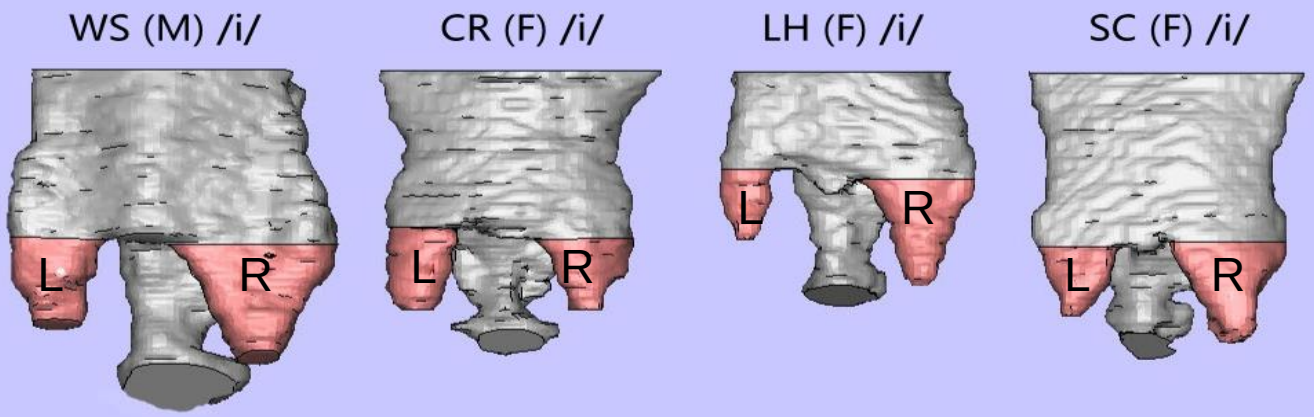
Results

1. Geometry of the left and right cavities of the piriform fossa

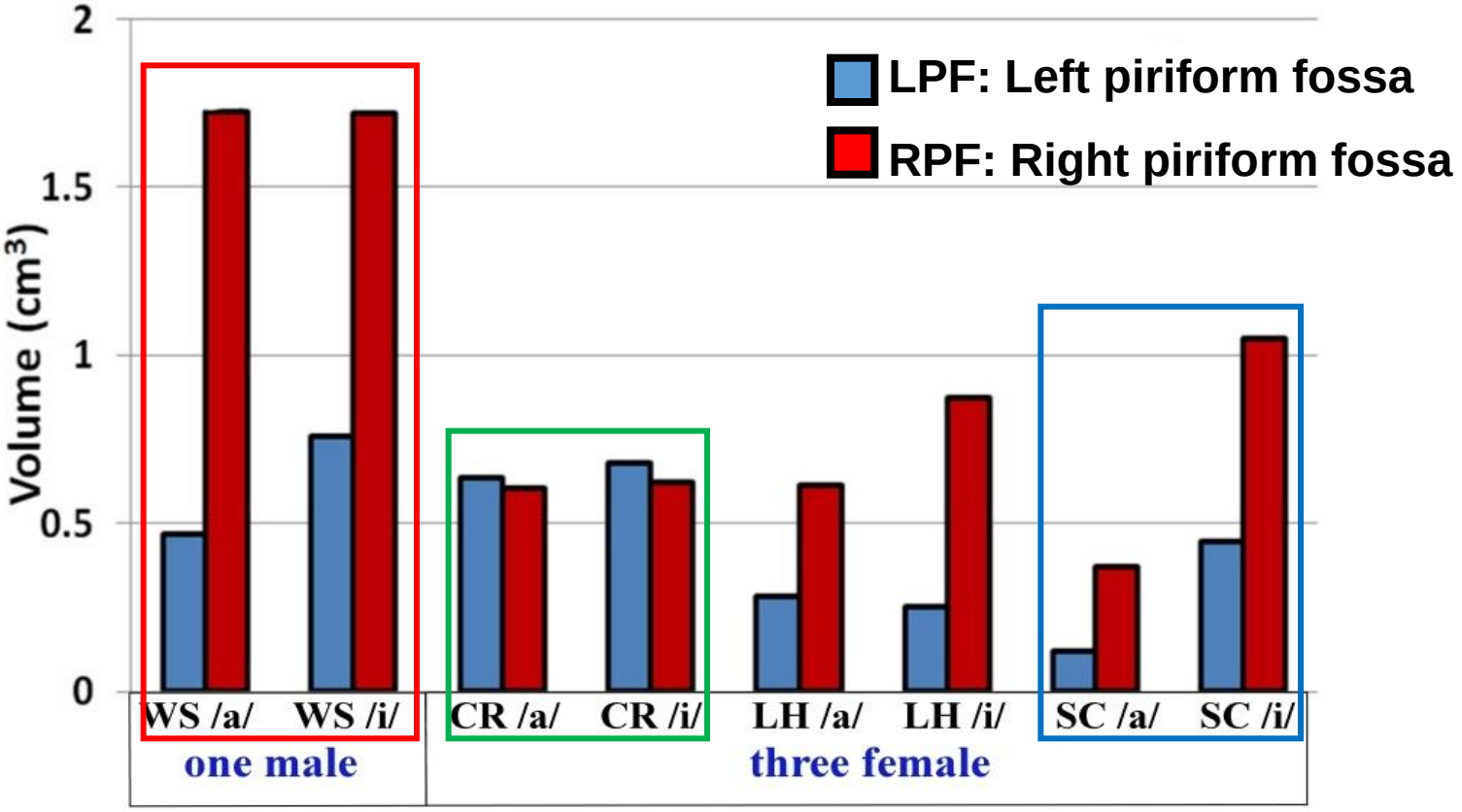
Back views of the lower part of 3D vocal-tract models



Left-right asymmetry of the cavities



1. Geometry of the left and right cavities of the piriform fossa



➢ **Summary**

a. Volumes of the fossa of WS (male) are larger than those in female's.

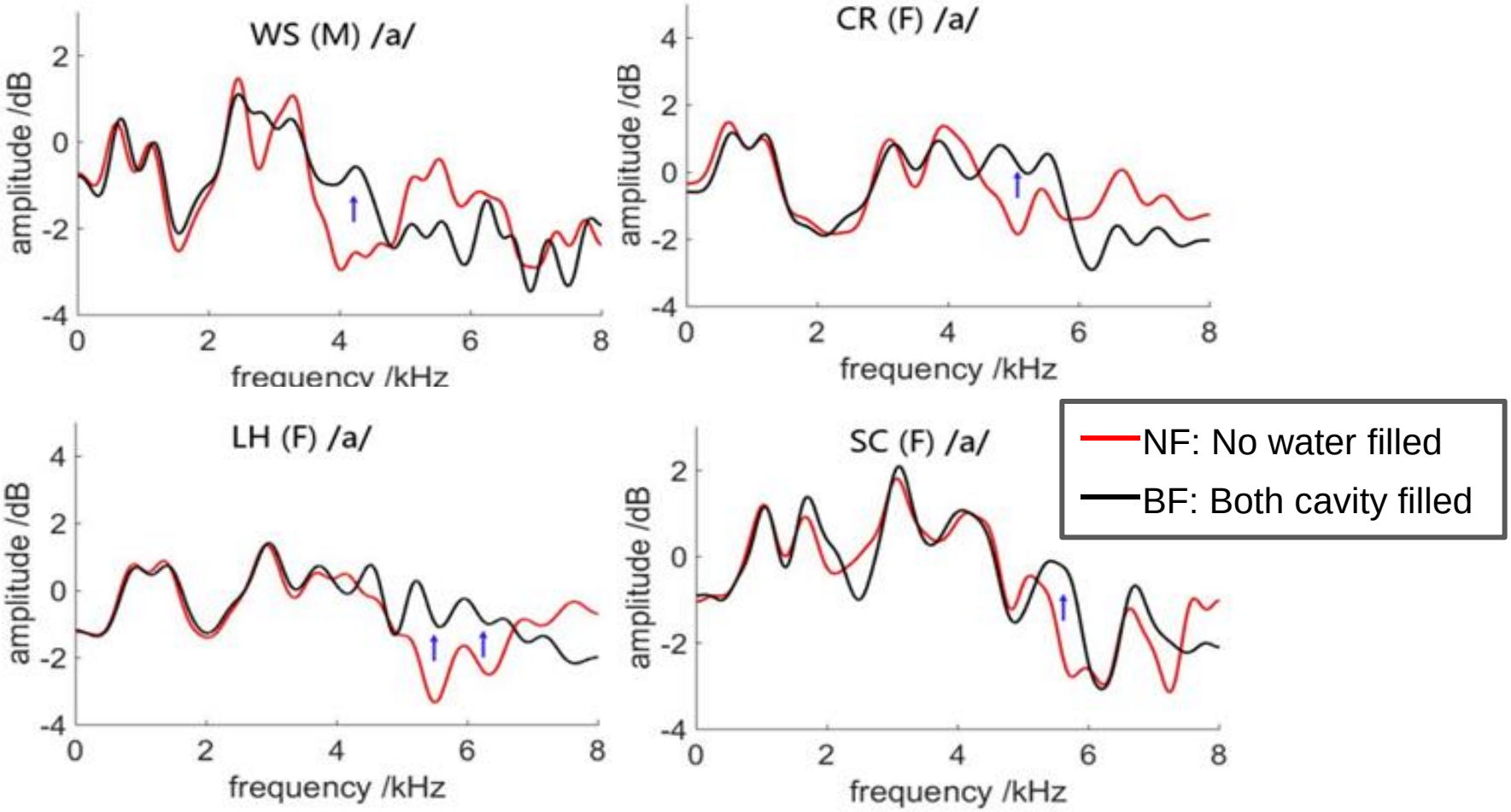
b. CR's volumes are symmetric, while in those of others, the right side is larger.

c. For SC's volumes, a marked difference in size between /a/ and /i/.

2. Anti-resonances of the piriform fossa in female vowel spectra

vowel /a/

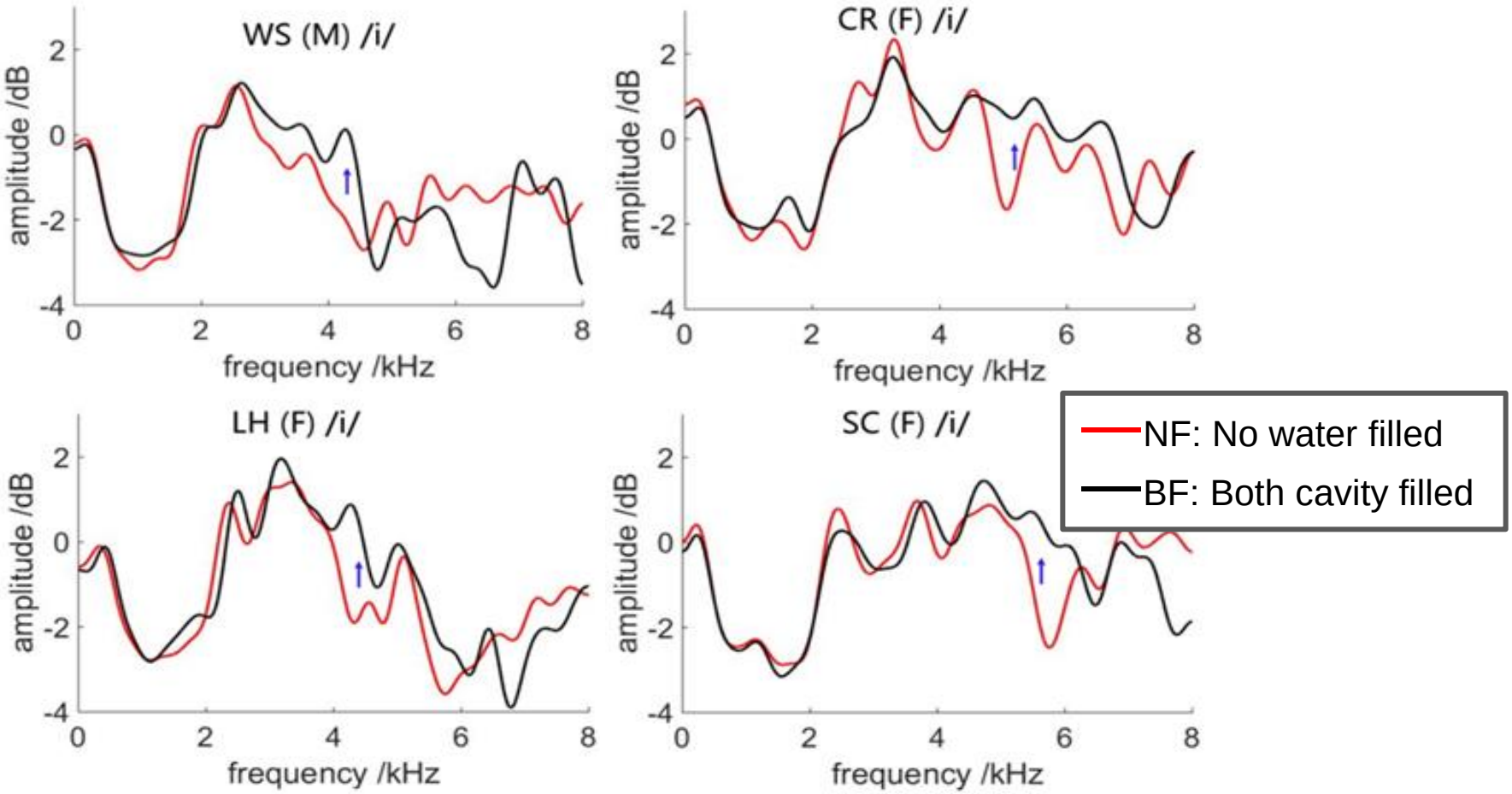
In two conditions of ‘NF: no water' (red) and ‘BF: filled with water' (black).



2. Anti-resonances of the piriform fossa in female vowel spectra

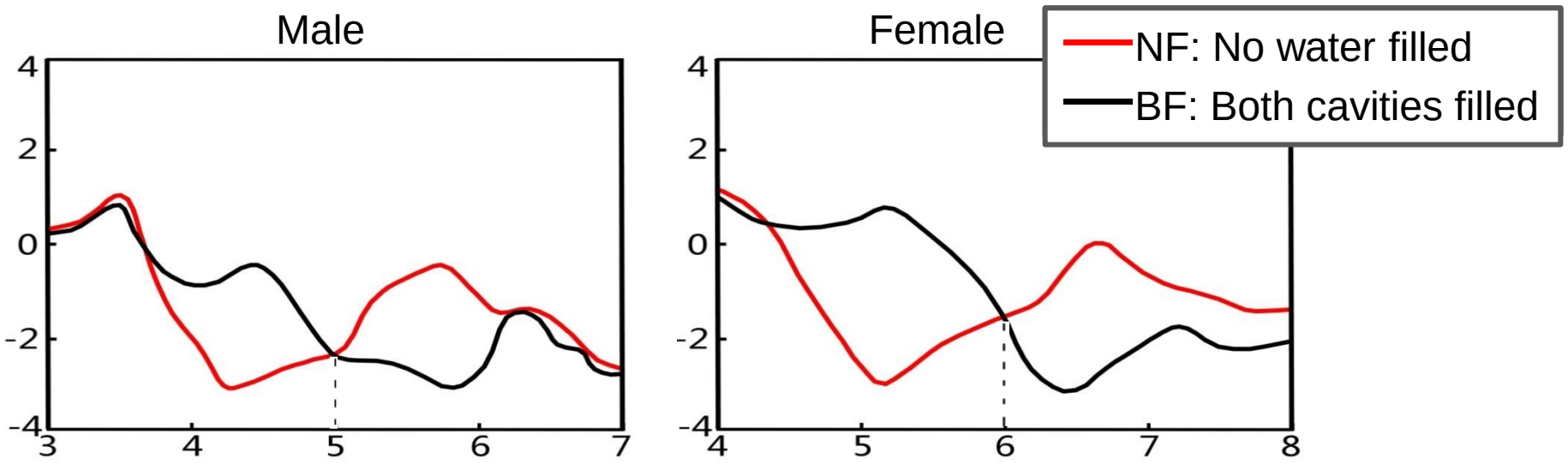
vowel /i/

In two conditions of ‘NF: no water' (red) and ‘BF: filled with water' (black).



2. Anti-resonances of the piriform fossa in female vowel spectra

Male and female spectra with and without the piriform fossa in water-filling experiment in vowel /a/

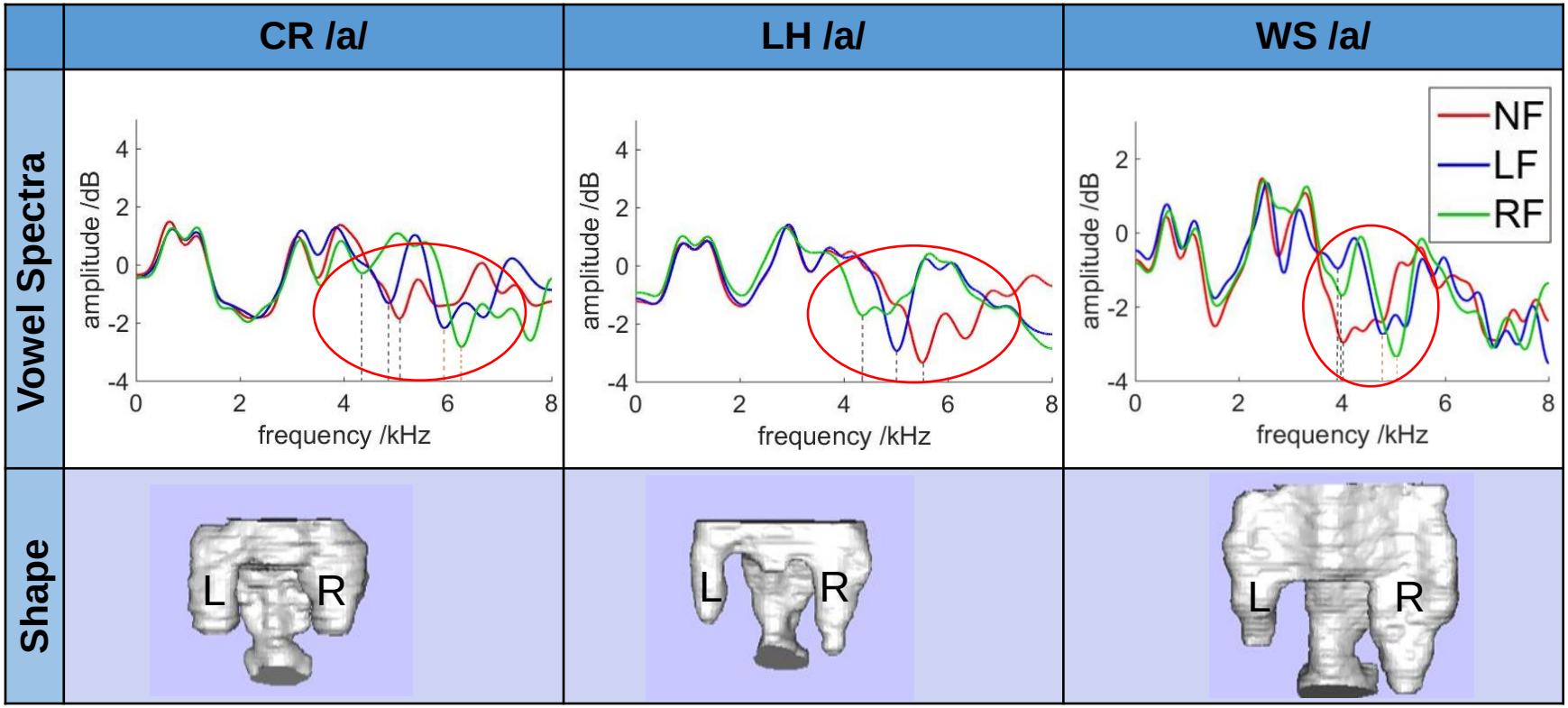


Male:
Dips are at **4-5** kHz
Peaks are at **5-6** kHz

Females:
Dips are at **4-6** kHz
Peaks are at **6-8** kHz

3. Effect of a single cavity

Spectra with no cavities filled (red), left filled (blue) and right filled (green).

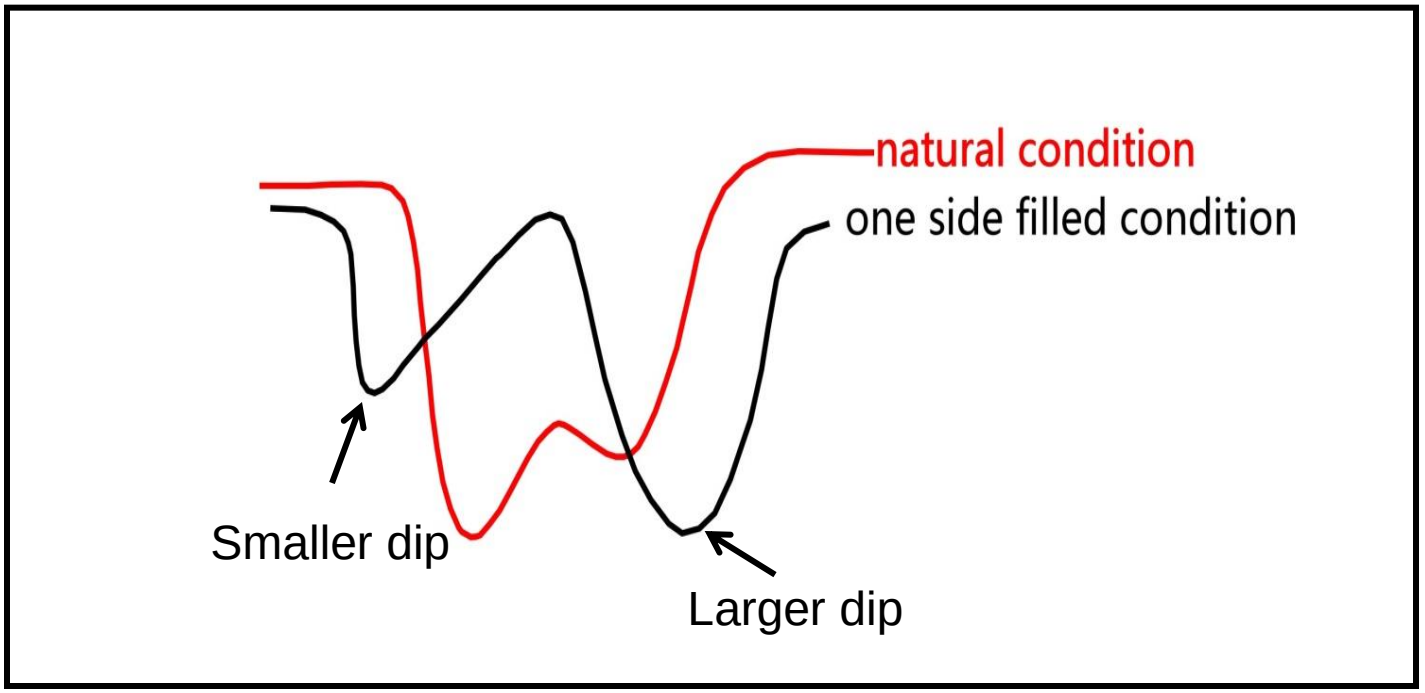


➢ **Q:** When one piriform fossa is filled:

- The tendency for LH /a/ may be reasonable. But in other case , they are not.
- Not only the length and Volume but also the shape influences the effect.

3. Effect of a single cavity suggests acoustic interaction.

A common pattern of the single-cavity effect



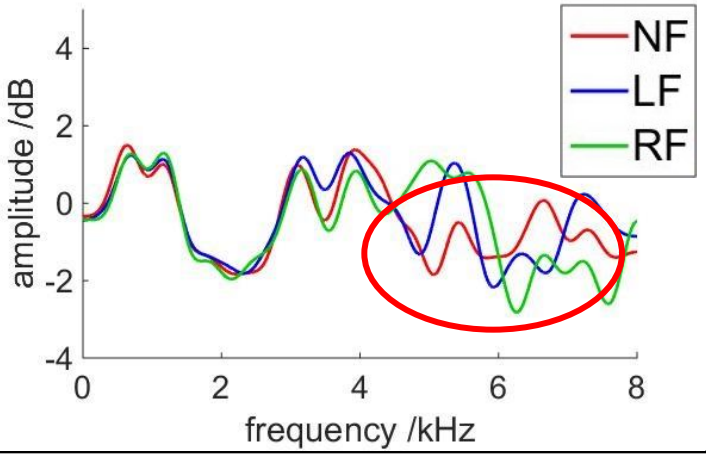
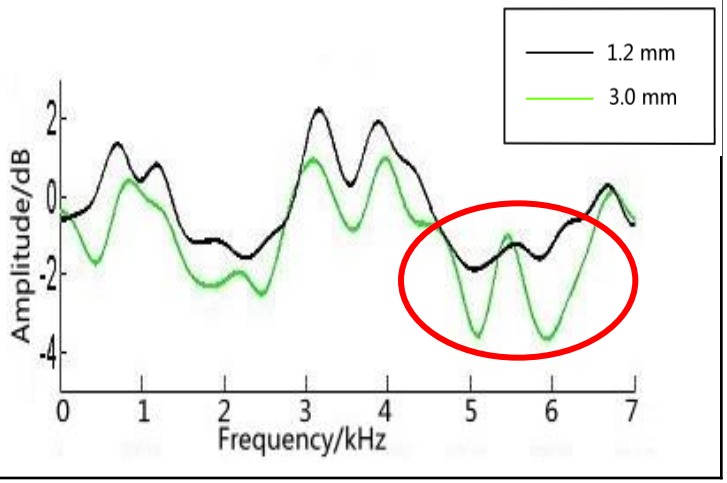
- **Two anti-resonance appear when one side is filled.**
  - Smaller anti-resonance appears at **lower frequencies**.
  - Larger anti-resonance appears at **higher frequencies**.

This pattern of interaction differs from Takemoto, et al. (2013).

4. Complex acoustic interaction

A possible explanation: The piriform fossa may also interact with the laryngeal cavity.

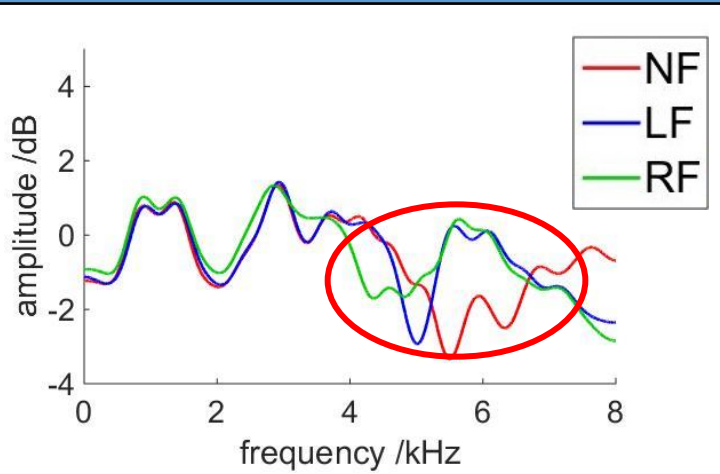
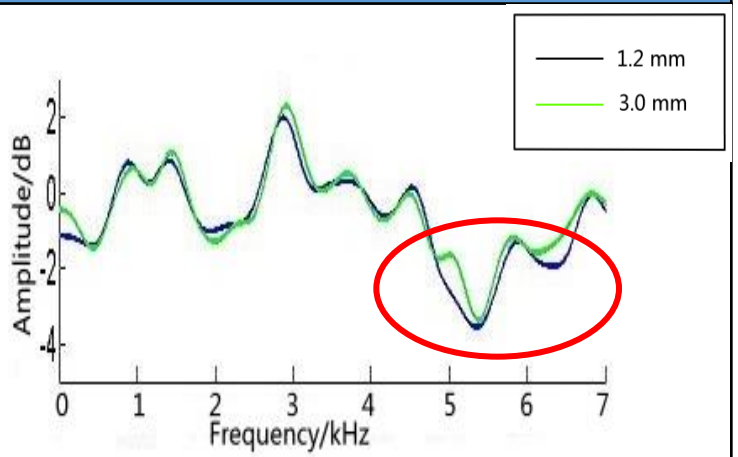
Higher frequency region (> 4kHz) is also influenced by the laryngeal cavity (Case 1).

	Effect of Piriform fossa	Effect of Laryngeal cavity
CR /a/		

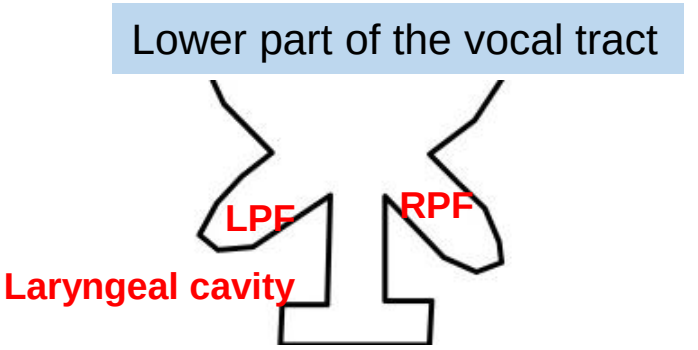
4. Complex acoustic interaction

A possible explanation: The piriform fossa may also interact with the laryngeal cavity.

Higher frequency region (> 4kHz) is also influenced by the laryngeal cavity (Case 2).

	Effect of Piriform fossa	Effect of Laryngeal cavity
LH /a/		

- **Interaction among three cavities (LPF, RPF and Laryngeal cavity)**



Discussion

1. What were discovered.

(1) The piriform fossa of our three female subjects exhibited **acoustic effects in the frequency region higher than the male case:**

- **Dips are at 4-6 kHz and peaks are at 6-8 kHz.**

(2) Acoustic interaction between the left and right cavities was observed with the **tendency**:

- **Smaller** anti-resonance appears at **lower frequencies**.
- **Larger** anti-resonance appears at **higher frequencies**.

2. Further study

Question remained: Why acoustic interaction between the left and right cavities are varied across speakers?

Thank you !

Acknowledgements

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