

# Relative Tongue Size as an Index to Predict Individual Articulatory Difference

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## Introduction

Background:

Speech clarity varies individually, but we don't know its causal mechanisms.

Purpose of study:

The **relative tongue size** gives an index about how far the tongue can move within the oropharynx. This study examines the relationship between the index and **tongue movement velocity** on MRI obtained from five Chinese speakers.

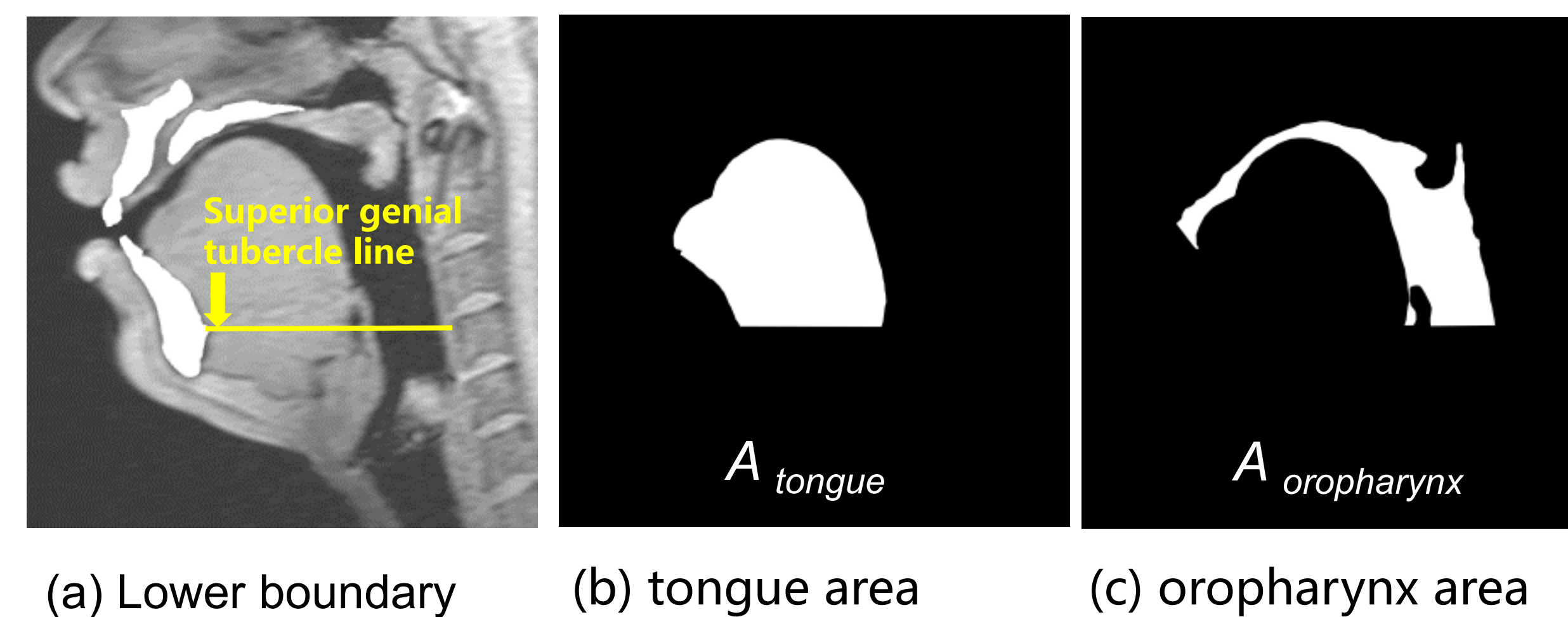
Methods:

- (1) Measurement of the relative tongue size on midsagittal MRI for /i/
- (2) Combined cine- and tagged-MRI to observe tongue motions.
- (3) Measurement of velocity of tongue surface markers.

## Method (1) Measuring relative tongue size

**Relative tongue size (RTS)** indicates tongue size relative to tongue + oropharynx size (above the boundary).

The smaller the *RTS*, the greater the tongue mobility in the oral and pharyngeal cavities.

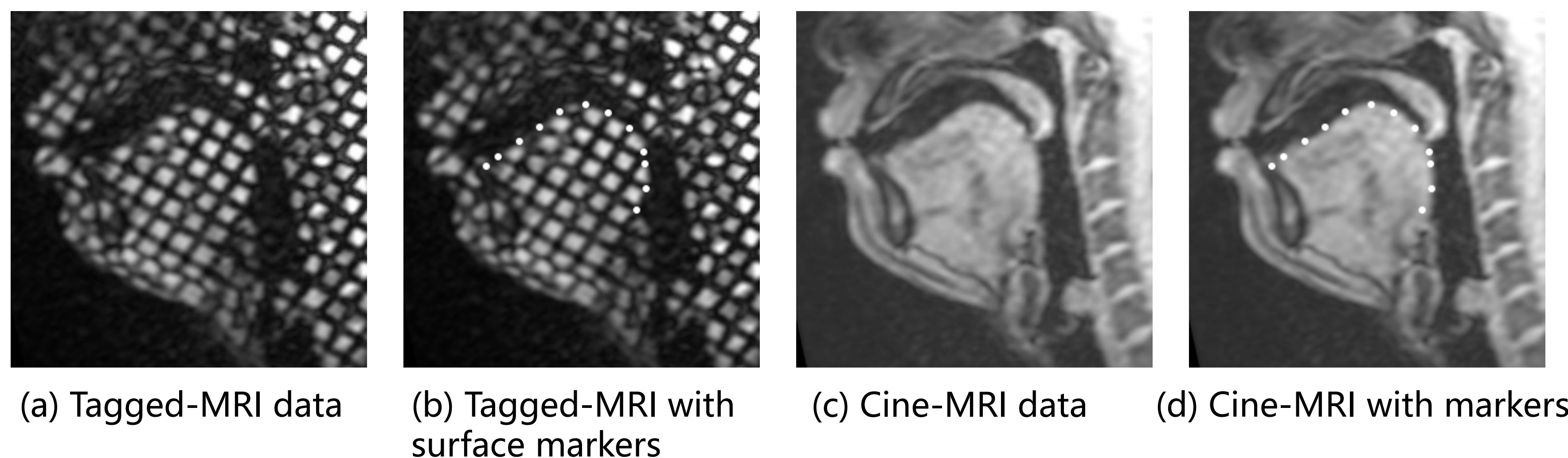


$$\text{Relative tongue size (RTS)} = \frac{A_{\text{tongue}}}{A_{\text{tongue}} + A_{\text{oropharynx}}}$$

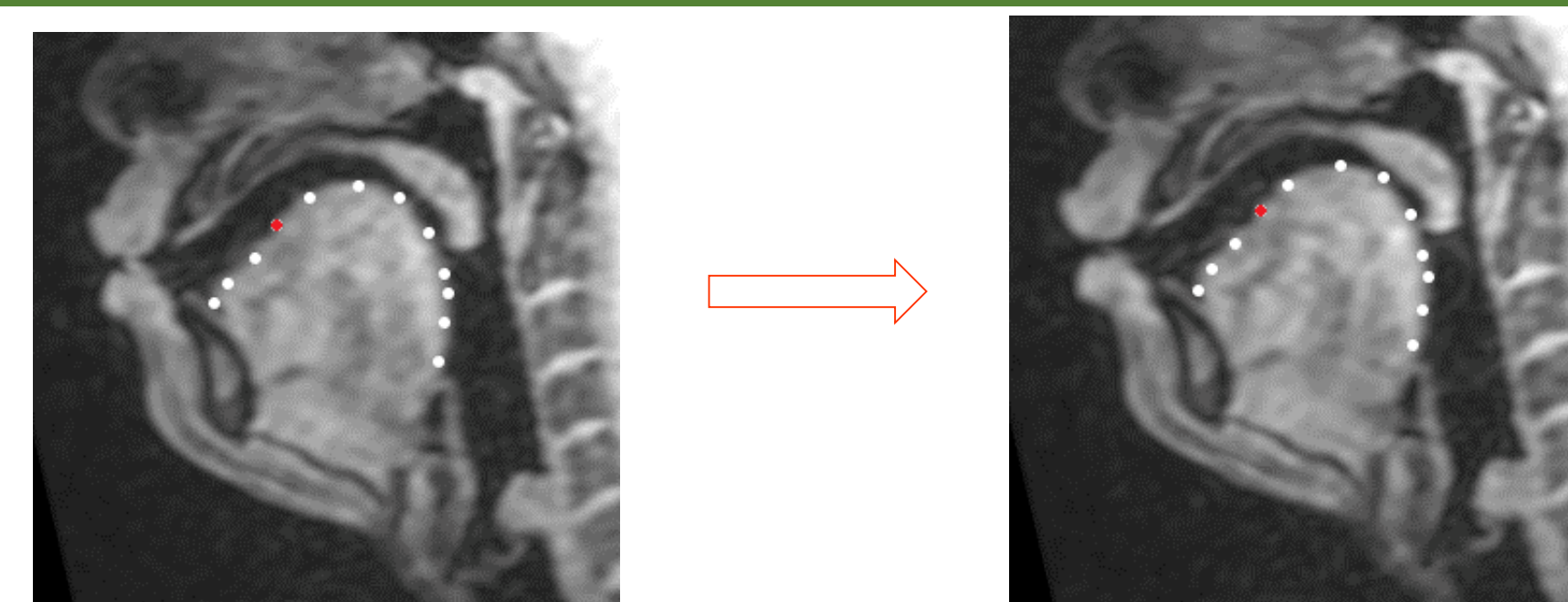
## Method (2) Analyzing combined cine- and tagged-MRI

MRI motion imaging was conducted with cine-MRI and tagged-MRI techniques in a single session.

Surface marker points were detected from tagged-MRI and mapped on cine-MRI data frame-by-frame.



## Method (3) Mean velocity of markers



Velocity of each marker point between two frames is:

$$v_{i,j \rightarrow j+1} = |P_{i,j} - P_{i,j+1}| / t$$

where  $P_{i,j}$  is point  $i$  in frame  $j$ , and  $t$  is the frame interval.

Mean velocity of all the selected points is:

$$\bar{v} = \frac{1}{N_p * (N_f - 1)} \sum_{i=1}^{N_p} \sum_{j=1}^{N_f-1} v_{i,j \rightarrow j+1}$$

where numbers of points and frames are  $N_p$  and  $N_f$ , respectively.

## Subjects and data

Five Chinese speakers of the north dialect

- Three females
- Two males

Test words

- /mune/ (木讷)
- /midu/ (密度)
- /mudi/ (目的)

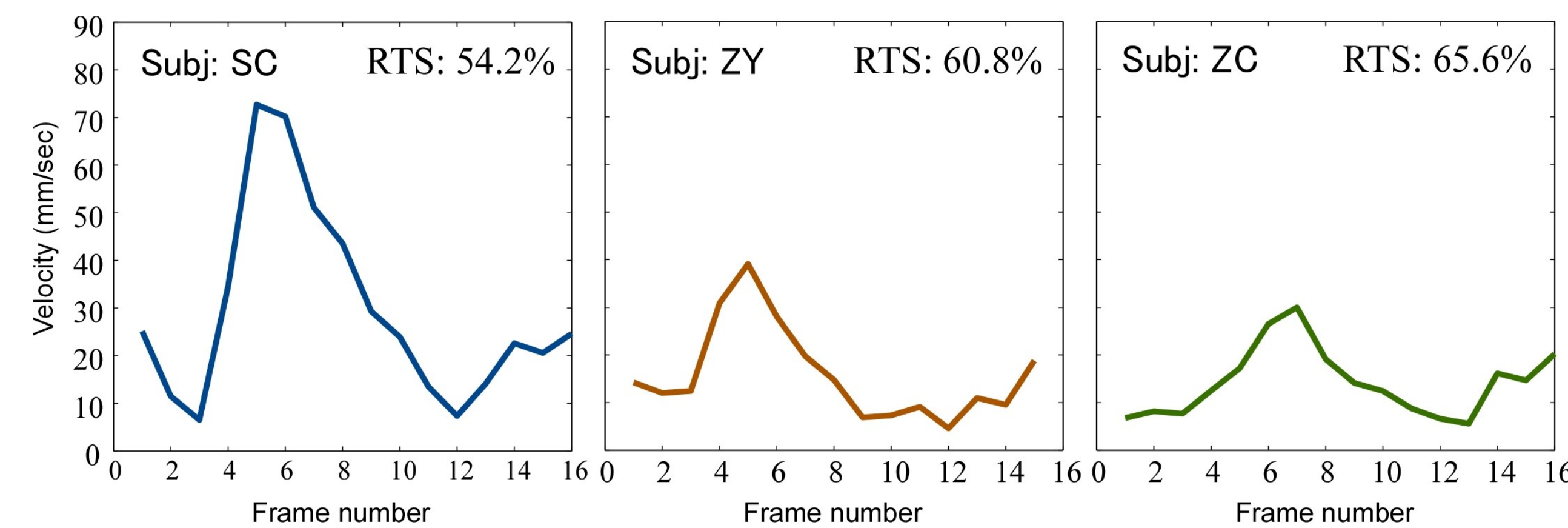
MRI experiments were conducted at ATR BAIC, Kyoto, Japan.

## Result (1) Relative tongue size

Subjects	Gender	Relative tongue size
S.C.	F	54.17%
Z.Y.	F	60.76%
Z.C.	F	65.57%
W.J.	M	55.56%
W.S.	M	62.68%

## Result (2) Example /mudi/: pharyngeal surface

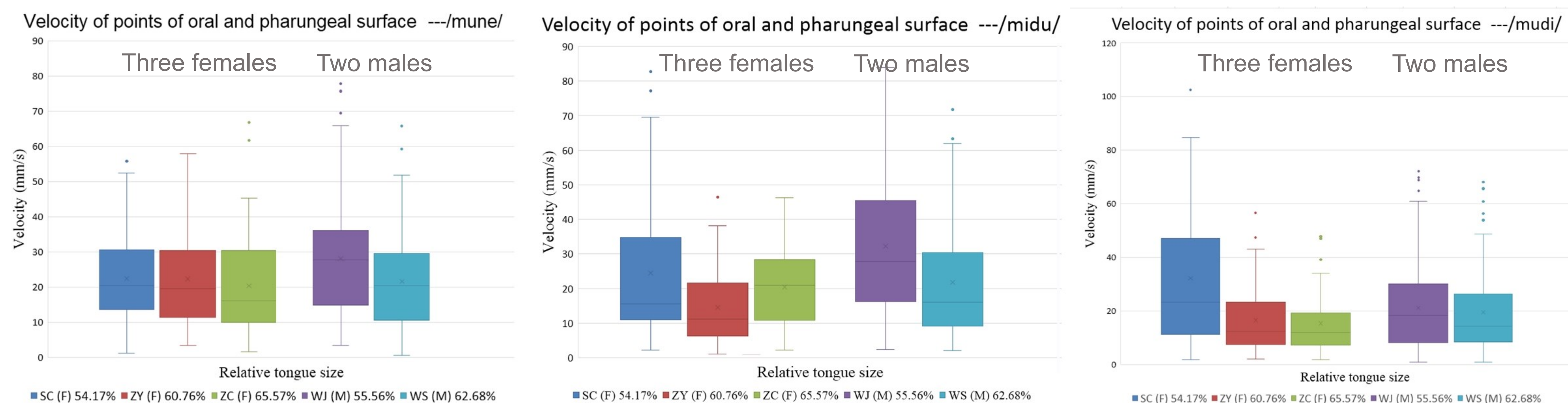
Velocity profiles (selected points) among three female speakers



## Result (2) Mean velocity: all the points

Subjects	Velocity (mm/s) /mune/	Velocity (mm/s) /midu/	Velocity (mm/s) /mudi/
S.C. (F)	22.48	24.51	31.10
Z.Y. (F)	22.36	14.46	16.62
Z.C. (F)	20.45	20.43	15.43
W.J. (M)	28.11	32.27	21.21
W.S. (M)	21.58	21.72	19.45

## Result (2) Box plot of mean velocity



## Result: Summary

- ❑ Among all the subjects, the relative tongue size ranged from 54.2% to 65.6%.
- ❑ Overall tongue surface velocities ranged from 14.5 mm/s to 32.3 mm/s. (The oral surface velocities ranged from 14.1 mm/s to 32.7 mm/s, and the pharyngeal surface velocities from 12.0 mm/s to 34.3 mm/s.)
- ❑ Comparison between the index and velocity for the male and female groups showed evidence that **the smaller the tongue, the faster the tongue movement.**

## Conclusion

- ❑ The **relative tongue size** predicts the mobility of the tongue within the cavity.
- ❑ This index infers a causal factor of individual articulatory difference and clarity of speech, also providing a hint to explore the nature of certain articulation disorders involving abnormal tongue size (e.g., Down syndrome).

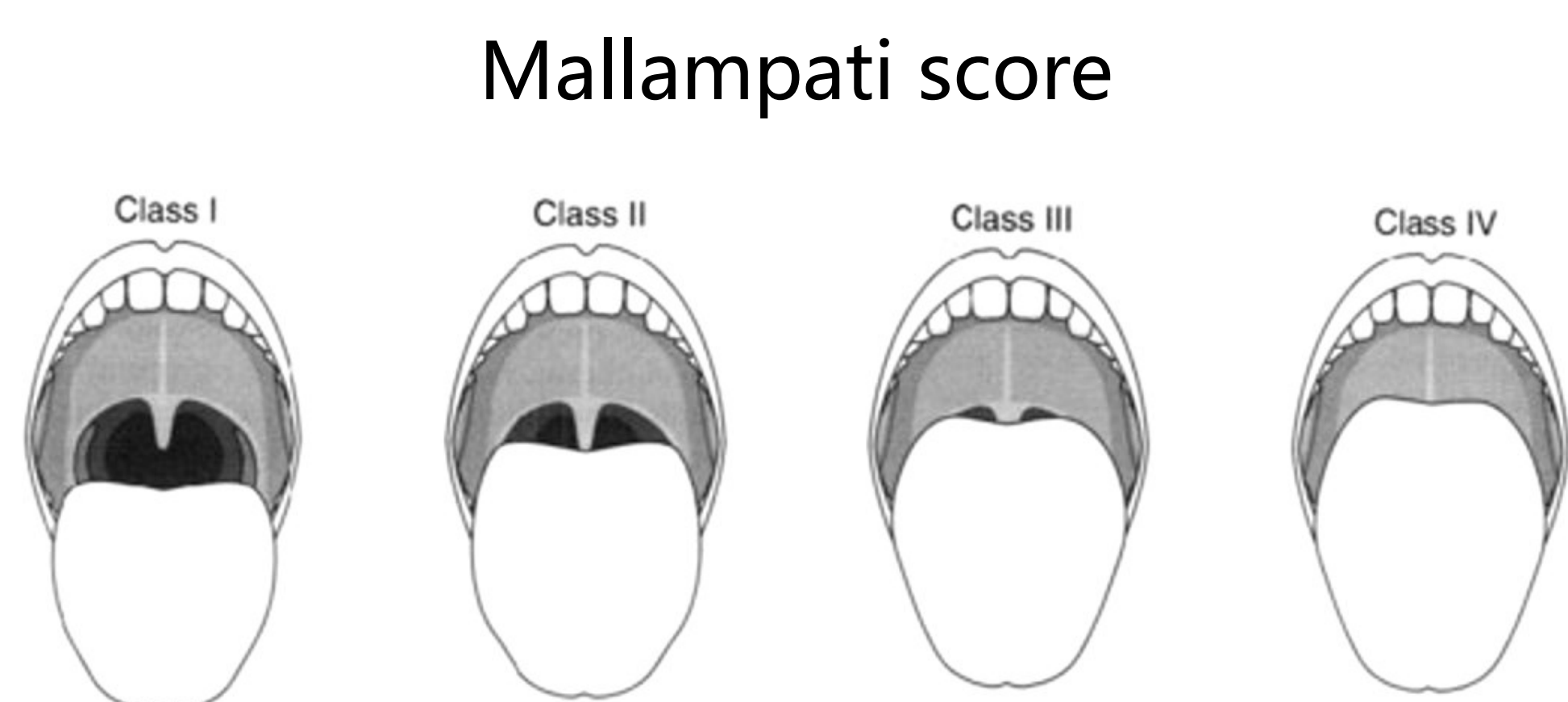
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## References

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2. Bao, H., Lu, W., Honda, K., et al. (2015) Combined cine- and tagged-MRI for tracking landmarks on the tongue surface. *Interspeech 2015*.
3. Honda, K., Bao, H., & Lu, W. (2016) Articulatory idiosyncrasy inferred from relative size and mobility of the tongue. *171st ASA Meeting*, Salt Lake City.

## Supplement 1: Classic scoring of relative tongue size

**Mallampati score** has been used to estimate the difficulty of intubation. This score is also a way to visually evaluate the relative tongue size. The accuracy is in question because of individual variation of the velum in length.



## Supplement 2: Data for the oral and pharyngeal surfaces

		Subjects				
Words/	Velocity (mm/s)	S.C. (F)	Z.Y. (F)	Z.C. (F)	W.J. (M)	W.S. (M)
/mune/	Velocity of oral surface	26.38	22.42	26.06	31.55	23.61
	Velocity of pharyngeal surface	18.58	22.29	12.04	24.68	19.56
/midu/	Velocity of oral surface	22.57	14.09	20.56	30.23	22.38
	Velocity of pharyngeal surface	26.45	14.84	20.24	34.31	21.07
/mudi/	Velocity of oral surface	32.73	17.34	16.27	23.07	20.11
	Velocity of pharyngeal surface	29.46	15.90	14.17	19.35	18.79