

An Investigation of the Acoustic Vowel Space of Singing

ICMPC 11
Seattle, WA

Introduction

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Speech and Singing

two modes of a system

Introduction

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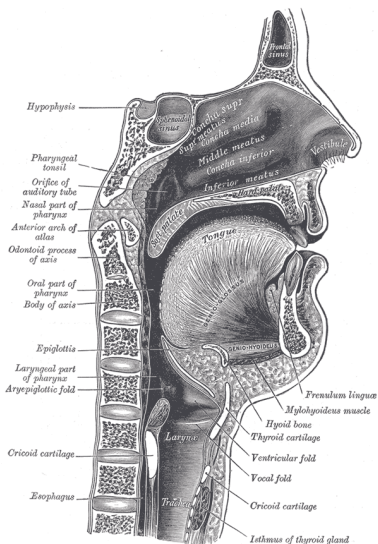
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- use the same vocal apparatus
- often contain linguistic content
- are subject to competing pressures
 - perceptibility
 - articulatory effort
 - aesthetics/style

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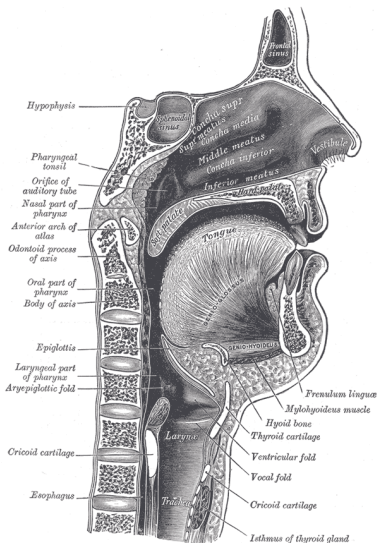
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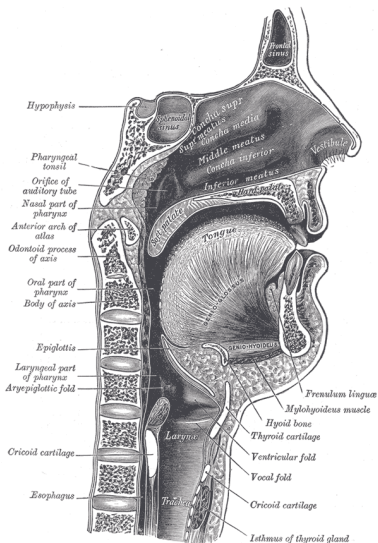
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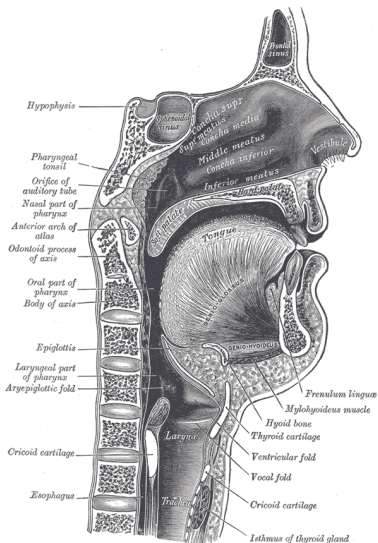
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- vowels are the most sonorous speech sounds
- the acoustic relationships among vowels are important for perceptibility
- vowels undergo articulatory modification in singing versus speech
 - (Sundberg et al., 2005; Sundberg, 1987; Howard and Collingsworth, 1992; Bloothoof and Plomp, 1986, 1984)
- How do these articulations affect the linguistic vowel space?

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Vowel Identity

Articulatory & Acoustic Space

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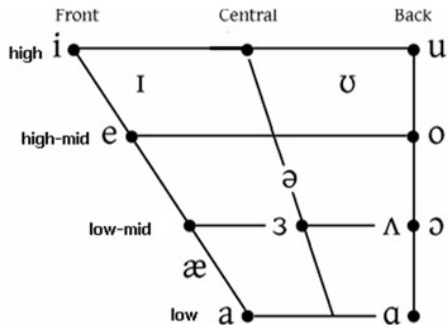
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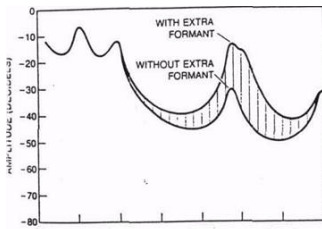
Larynx Height

(Sundberg, 1987)

- in normal speech, larynx height varies with pitch
- trained singers maintain lower larynx
 - lengthens vocal tract, changing resonances
 - creates *singer's formant*

'Singer's Formant'

(Sundberg, 1987)



- clustering of formants 3–5 \approx 3000Hz
 - increases perceived loudness without increasing SPL
 - also lowers formants 1–3, resulting in vowel migration
 - $i \rightarrow y$
 - $a \rightarrow o$
 - gender differences due to range and anatomy

'Singer's Formant'

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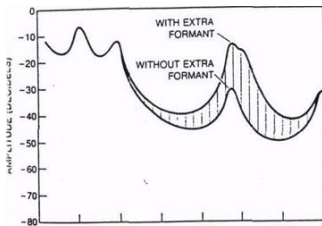
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Singing & Vowels

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- most previous studies have evaluated vowels in isolation
- examine vowels in context during singing and speaking by the same singer to look for systematic effects on the linguistic vowel space

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- 16 singers, 8 female (1 male eliminated due to excessive errors)
- several years of vocal training, or experience in semi-professional and collegiate choirs
- native speakers of American English, Mid-Atlantic region
- age 18–77 (mean 25.8)

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- *Shenandoah*, traditional American (Lomax, 1960)

O Shenandoah, I long to hear you.

Away, you rolling river.

O Shenandoah, I long to hear you

Away, we're bound away

Across the wide Missouri.

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o fænəndoə ai loŋ tu hir ju
əwei ju ɹoŋ ɹivə
o fænəndoə ai loŋ tu hir ju
əwei wɪ bʌʊnd əwei
əkɹɔs ðə wɔɪd mɔɪzɪ

Music

Vowel Selection

o fænəndoə ai lɔŋ tu hir ju
əwei ju ɹɔlɪŋ ɹɪvə
o fænəndoə ai lɔŋ tu hir ju
əwei wɪ bʌʊnd əwei
əkɪs ðə waɪd mɪzɪ

Music

Vowel Selection

o fænənd^oə aɪ lɔŋ tu hir ju
əweɪ ju ɹoɪŋ ɹɪvə
o fænənd^oə aɪ lɔŋ tu hir ju
əweɪ wɪ bʌʊnd əweɪ
əkɹɔs ðə wɑɪd mɪzɪ

Procedure | Analysis

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- 1 speak the lyrics of each piece, in the manner of a poem
- 2 sing each piece *a cappella*
 - transposed to appropriate octave for each singer
 - (relatively) free tempo
- 3 first and second formants measured using PRAAT
- 4 formant values regressed on sex, phonological vowel height [lo, mid, hi] and frontness [front, back]

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1 larynx lowering suggests lower formants overall in singing

- greater f_1 effect for *low* vowels than *high* vowels
- greater f_2 effect for *front* vowels than *back* vowels

2 possible gender differences

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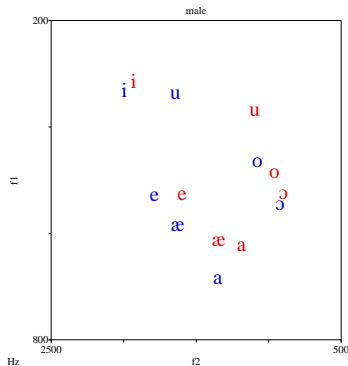
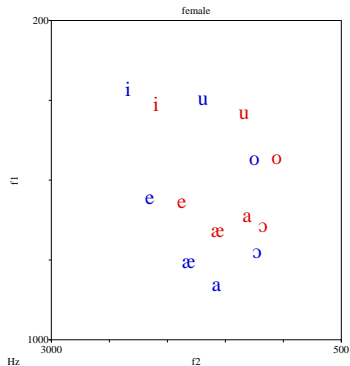
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Results

Overall Effects of Singing



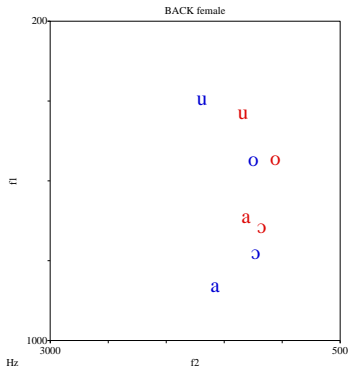
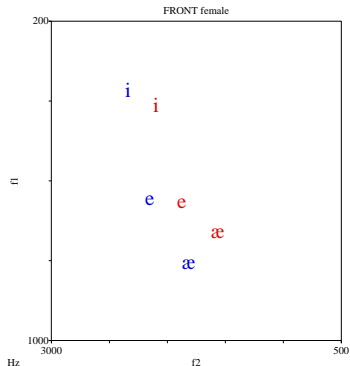
SPEAK SING

- near sig.¹ effect on f_2 (across gender)
- no sig. overall effect on f_1 (across gender)

¹ $p = 0.065$

f_2

Vowel Class Differences



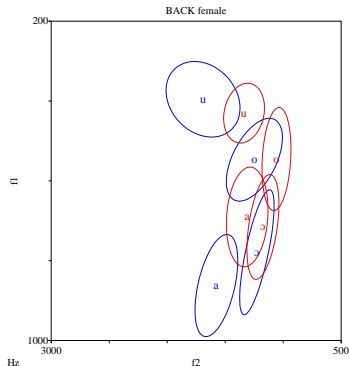
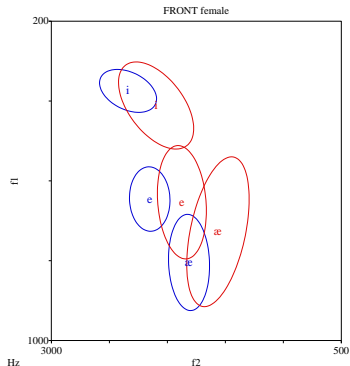
SPEAK **SING**

- sig.² effect of singing on f_2 of front vowels versus back vowels (200Hz across gender)
- for some vowels, greater variation of f_1

² $p = 0.005$

f_2

Vowel Class Differences



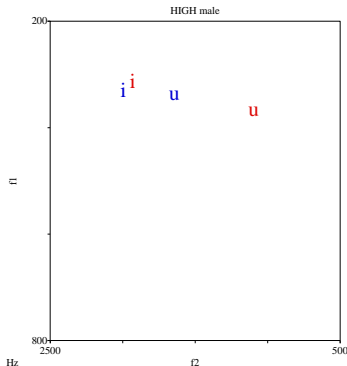
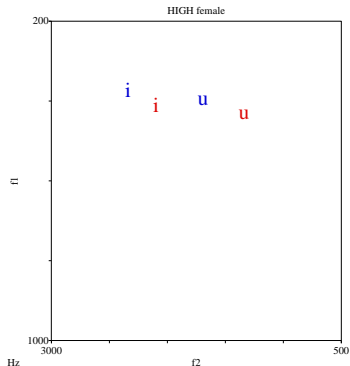
SPEAK $z = 1$ **SING**

- sig.³ effect of singing on f_2 of front vowels versus back vowels (200Hz across gender)
- for some vowels, greater variation of f_1

³ $p = 0.005$

f_2

Gender Differences

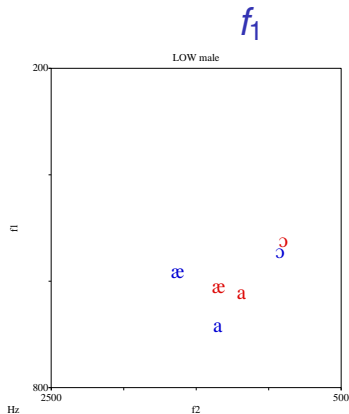
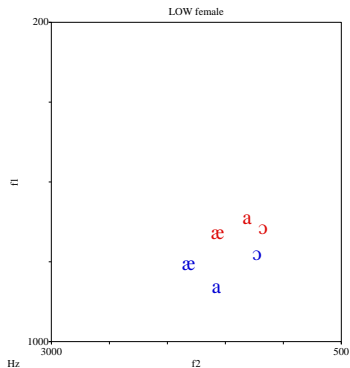


SPEAK $z = 1$ SING

- sig.⁴ greater effect of singing on f_2 of high vowels
- sig.⁵ difference between males and females on high-front vowel [i]

⁴ $p = 0.001$

⁵ $p = 0.009$



SPEAK $z = 1$ SING

- no overall effect of singing on f_1 , but trend⁶ toward effect of height driven by low vowels
- height effect is stronger⁷ for females

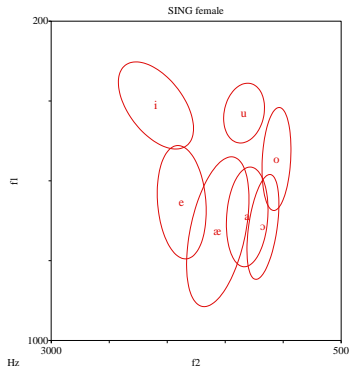
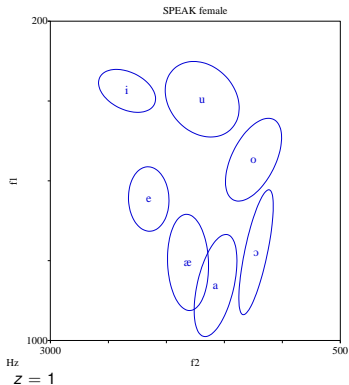
$$^6 p = 0.097$$

$$^7 p = 0.012$$

Vowel Space Change

Female

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Vowel Space Change

Male

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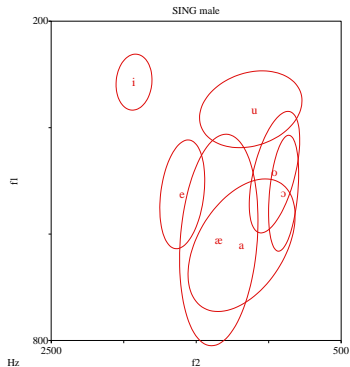
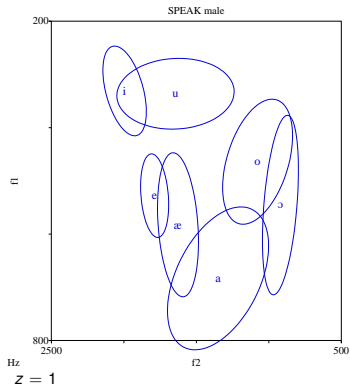
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- in the current study, singing lowered the first and second formants of vowels
 - vowel class differences were (somewhat) consistent with expectations ($f_1 \rightarrow$ low, $f_2 \rightarrow$ front)
- gender differences could be due to experience differences between males and females
 - all female singers were semi-professional, or active vocal majors; not all males were

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- effects of singing on the acoustic vowel space:
 - *acoustic* shift and compression front to back
 - overlap of low vowels with mid
- may have consequences for perceptibility of lyrics

Summary

Future Research

- use naturalistic phonetic comparison of singing to examine:
 - degree and kind of training
 - musical style
 - with careful design, micro changes within piece, such as pitch
 - effects of f_3 and f_4 on vowel spaces of rounding and rhoticity

Acknowledgments

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- UDel Department of Music
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- Laura Evans & Liam Evans-Bradley



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