ARTICULATORY-ACOUSTIC RELATIONS IN GERMAN VOWELS

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ABSTRACT

This work examines whether articulatory-acoustic relationships familiar from modelling studies are actually observable in speakers' utterances. Using electromagnetic articulography the relation between formant frequencies and constriction location and size was examined in /i/, /e/, /y/ and /ø/.

F2 vs.constriction location: Correlations were close to zero. This applied to both unrounded and rounded vowels.

F2 vs. constriction size: Correlations were moderately strong. However, the slope of the relationship was surprisingly flat, around 20 Hz/mm.

F1 vs. constriction size: Correlations were very strong, but with flatter regression slope for rounded than unrounded vowels. Some articulatory compensation for the flatter slope in rounded vowels was observed.

While overall trends were much as expected, variability over speakers was sometimes quite marked. Better understanding of how and why speaker-specific differences in articulatory-acoustic relationships occur will require linking the EMMA data with area-function data from NMRI and using a vocal-tract model to try and reproduce the empirically observed relationships.

PROCEDURE

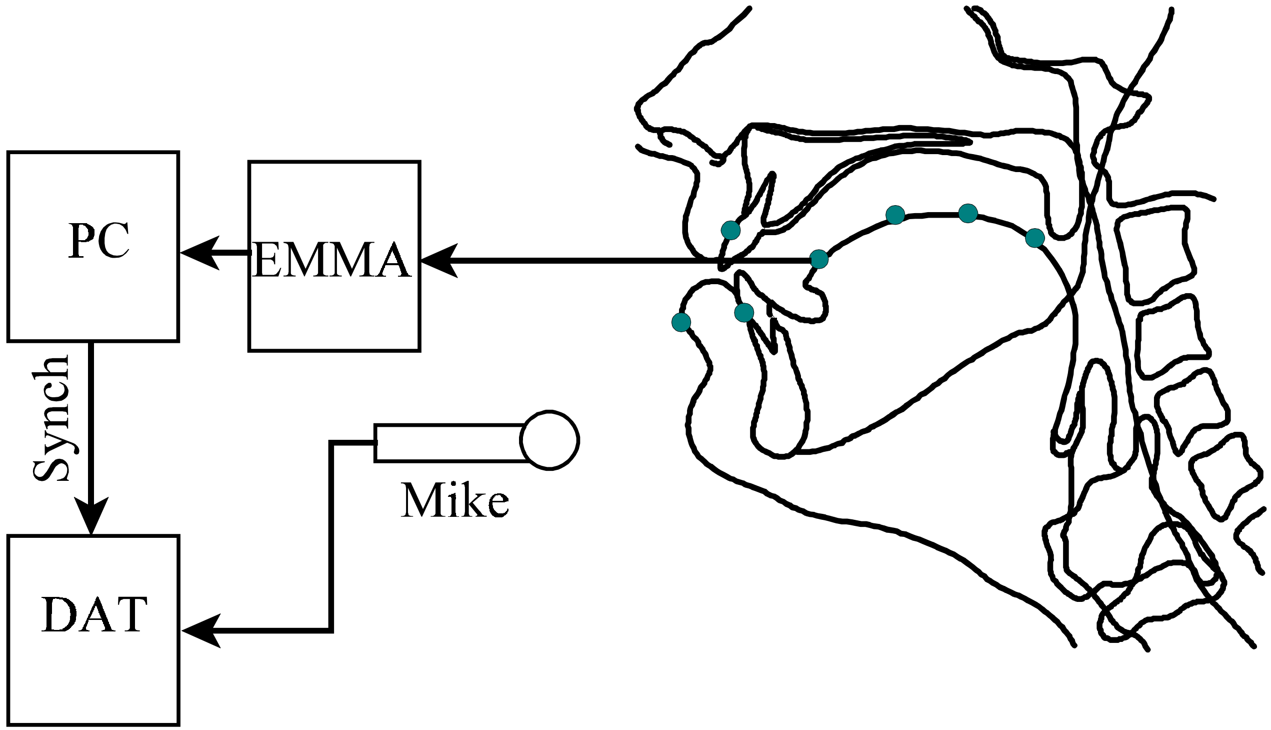
/i/, /e/, /y/ and /ø/ (“palatal” vowels selected from a larger dataset)

3 consonant contexts: /p/, /t/ and /k/.

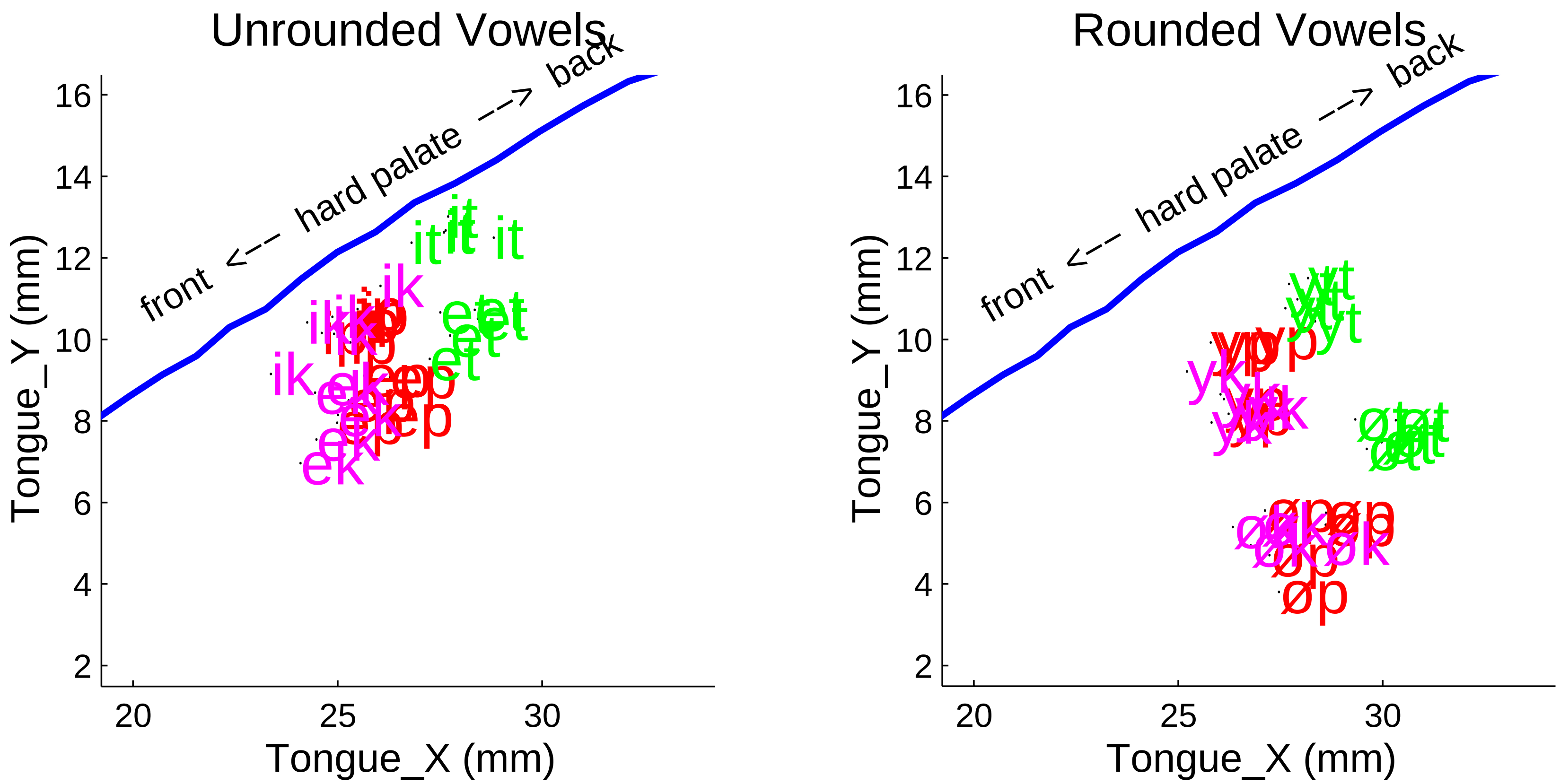
5 repetitions of each CV combination

Data of second tongue sensor from the front was selected at vowel midpoint and converted to palate-based coordinates:

- constriction location: position along hard palate
- constriction degree: position perpendicular to hard palate

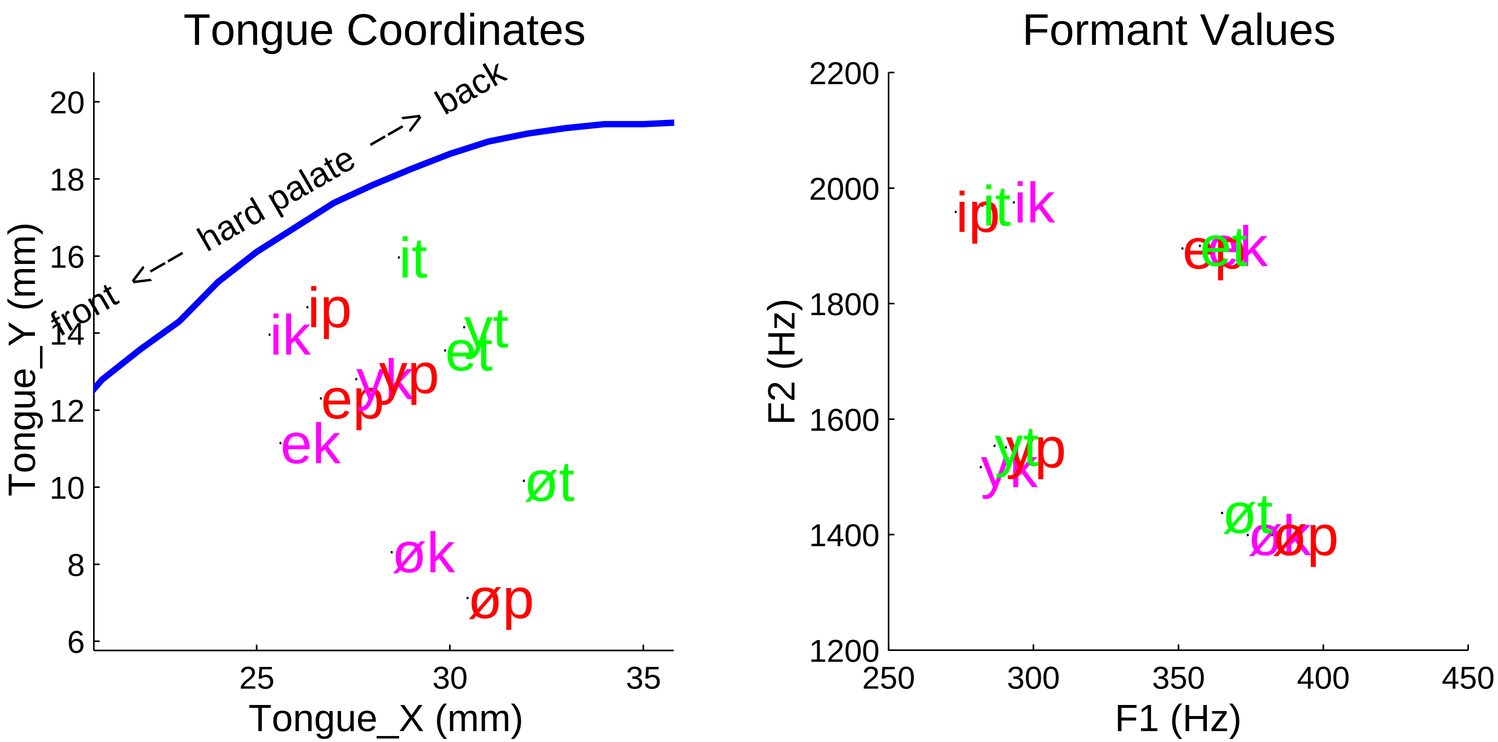

PC
EMMA
Synch
Mike
DAT

Speaker C



Raw articulatory data for one subject

Average of 6 male speakers



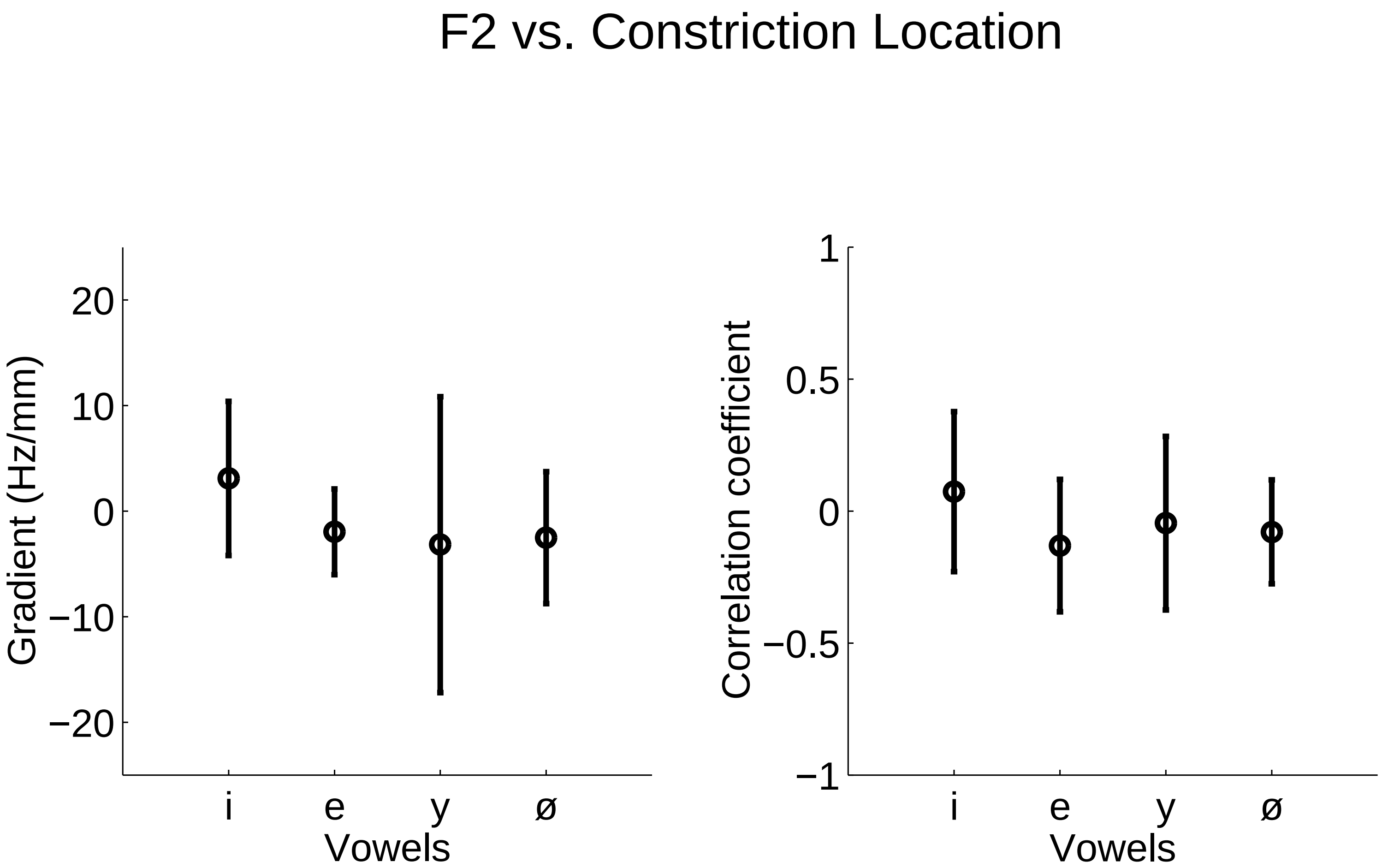
Average Articulatory Data (left) and Acoustic Data (right). Note: coarticulatory effects are much clearer in the articulatory data

RESULTS

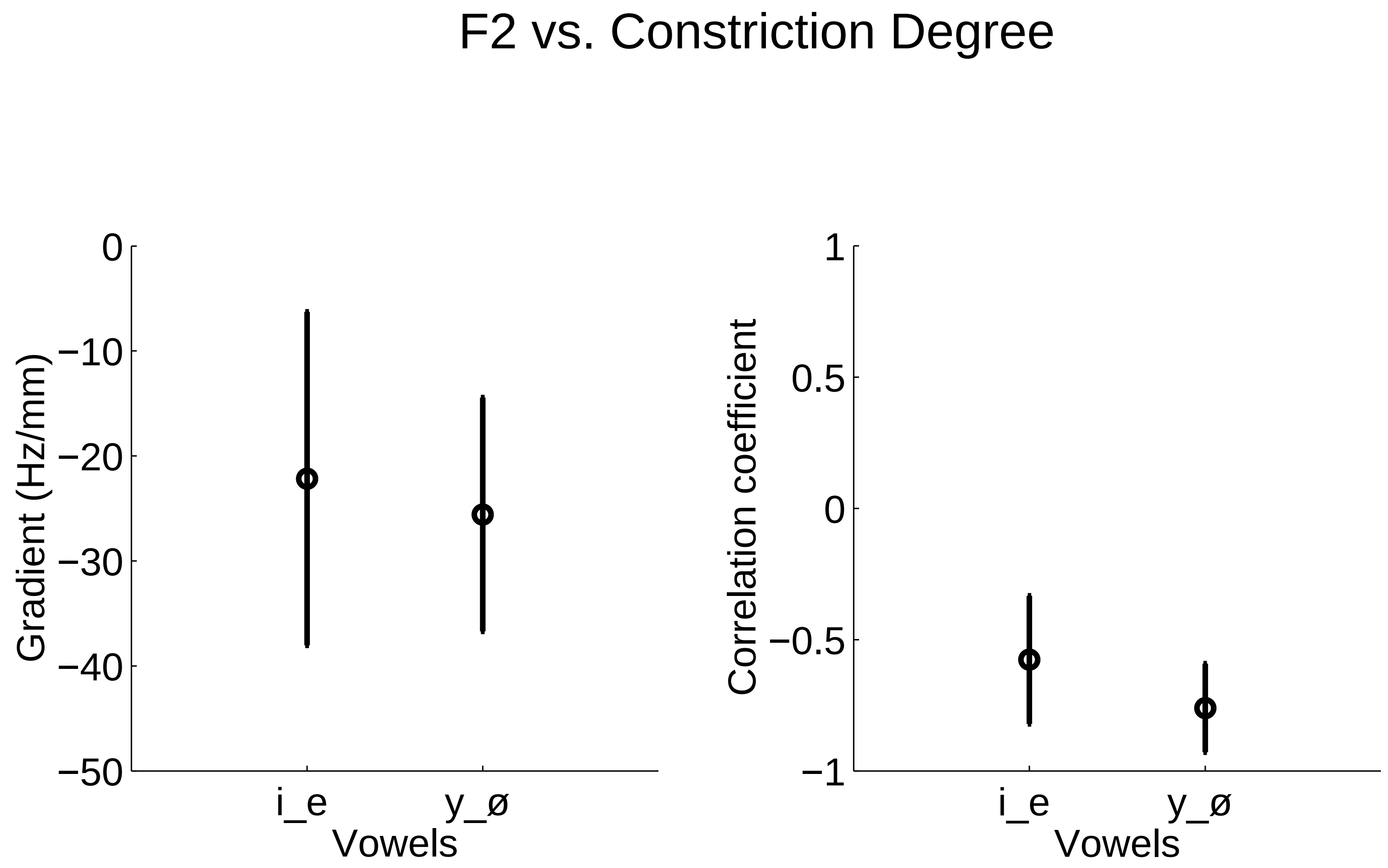
Three selected articulatory-acoustic relations are shown below.

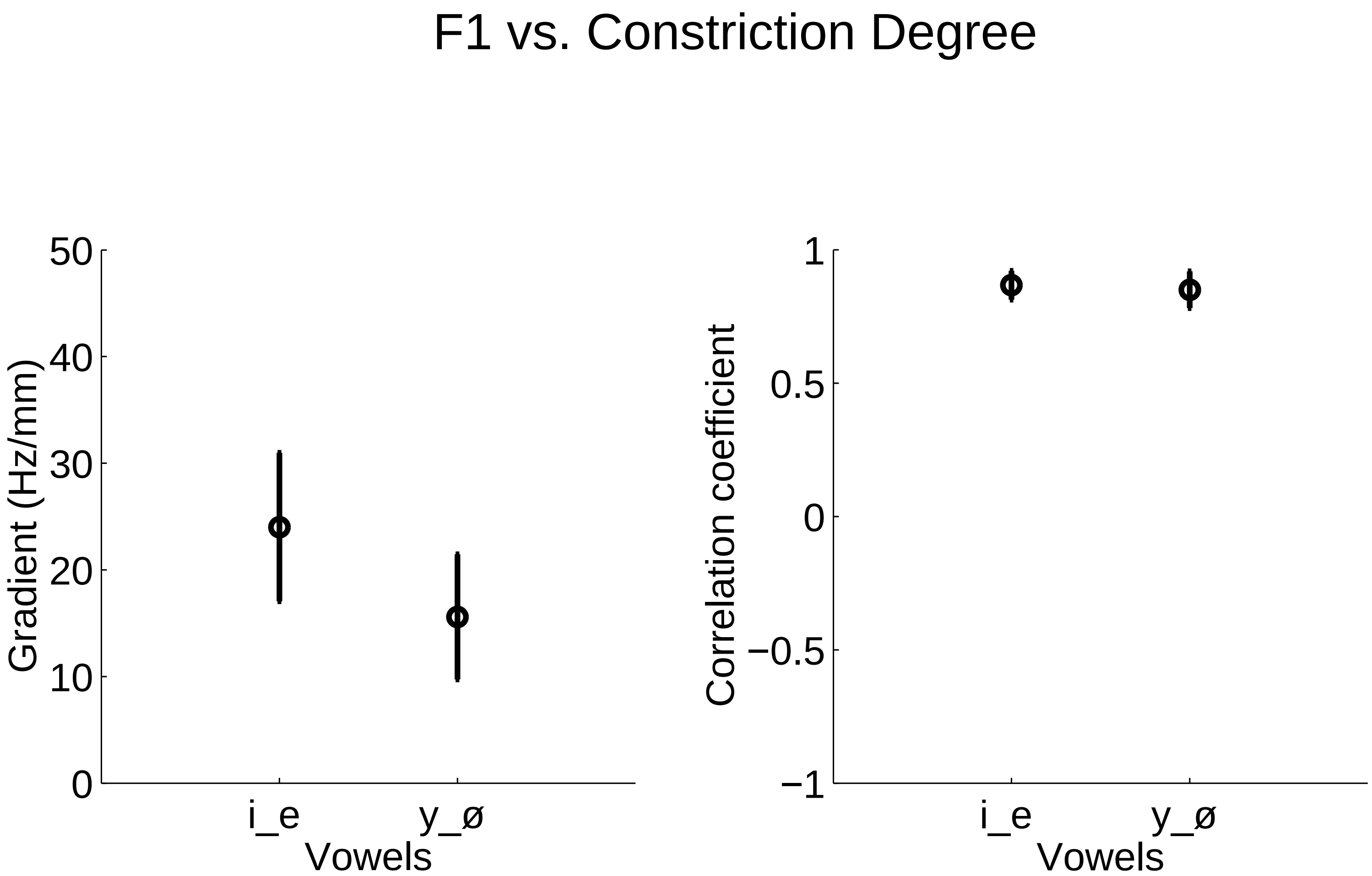
Each relationship is expressed in terms of

- the **gradient** (left panels):
  - *formant change in Hertz per millimetre of tongue movement*
- the **correlation coefficient** (right panels)



F2 vs. Constriction Location
Gradient (Hz/mm)
20
10
0
−10
−20
i
e
y
ø
Vowels
Correlation coefficient
1
0.5
0
−0.5
−1
i
e
y
ø
Vowels


F2 vs. Constriction Degree
0
−10
−20
−30
−40
−50
Gradient (Hz/mm)
i_e
y_ø
Vowels
1
0.5
0
−0.5
−1
Correlation coefficient
i_e
y_ø
Vowels



F1 vs. Constriction Degree
Gradient (Hz/mm)
50
40
30
20
10
0
i_e
y_ø
Vowels
Correlation coefficient
1
0.5
0
−0.5
−1
i_e
y_ø
Vowels

Main Observations

F2 vs. Constriction Location

No systematic relationship

neither for unrounded vowels (cf. Stevens; Beckman et al.),

nor, more importantly, for rounded vowels (cf. Wood)

F2 vs. Constriction Degree

Relationship systematic both for unrounded and rounded vowels

but the gradient is very shallow (re. Beckman et al.)

/i/ vs. /e/ distinction could not be learnt on this basis

F1 vs. Constriction Degree

Relationship highly systematic (heavens be praised!)

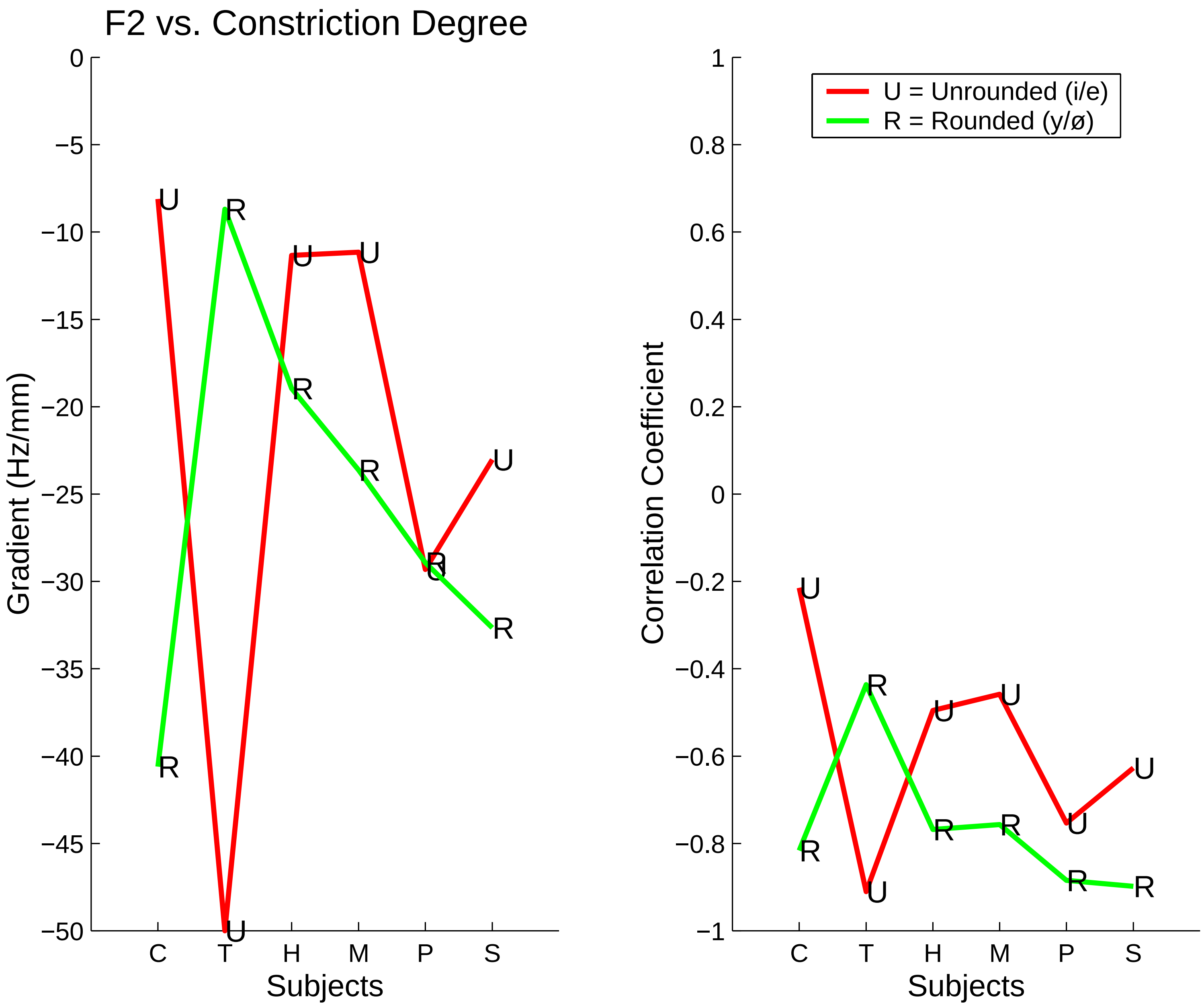
But note consistently shallower gradient in rounded vowels

There appears to be some articulatory compensation for this

THE NEXT STEPS

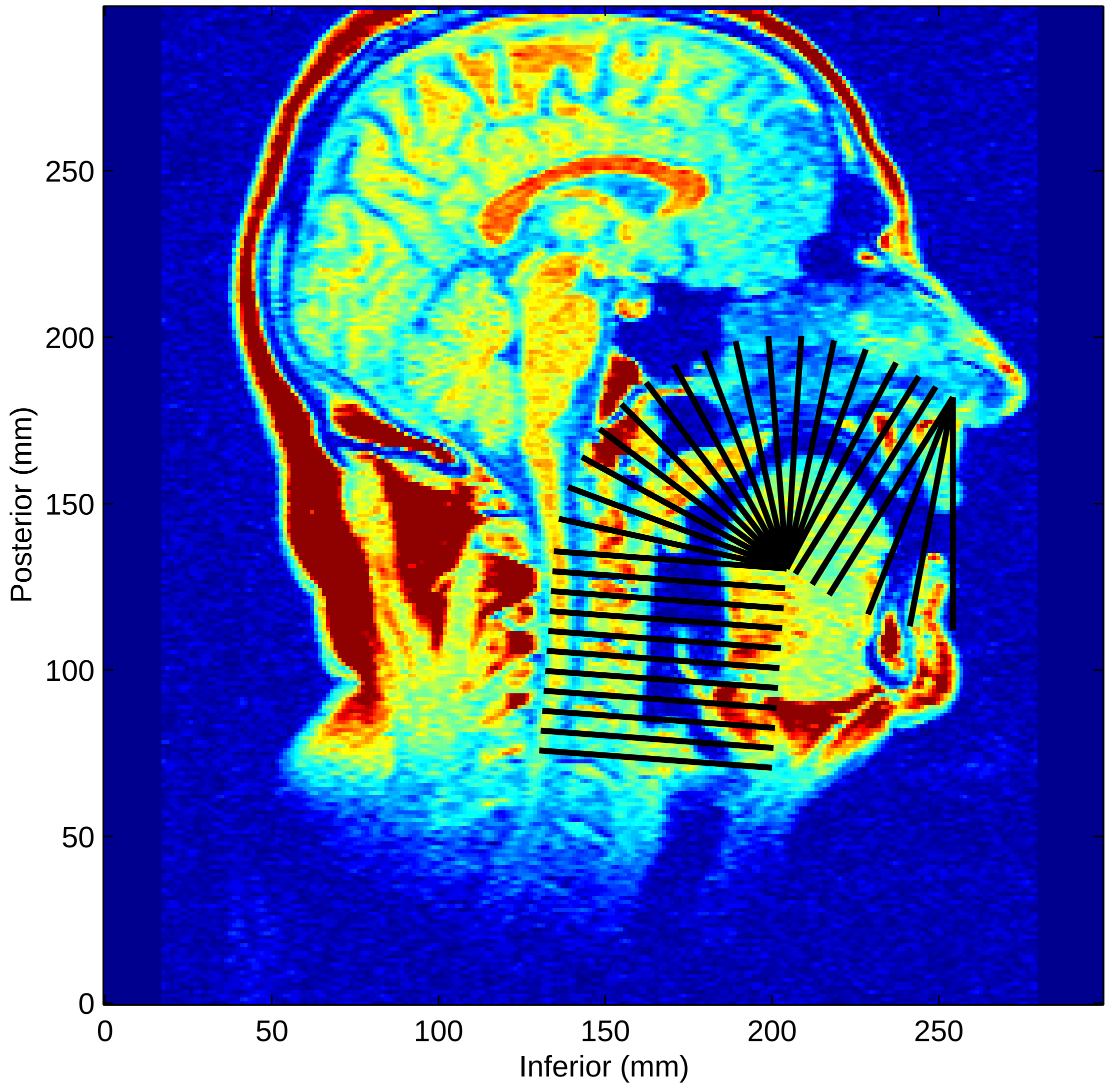
Overall trends conformed largely to expectations.
However, *individual* results sometimes differed markedly from the general pattern (note size of error bars in previous figures).

The following figure breaks down F2 vs. Constriction Degree by subject.

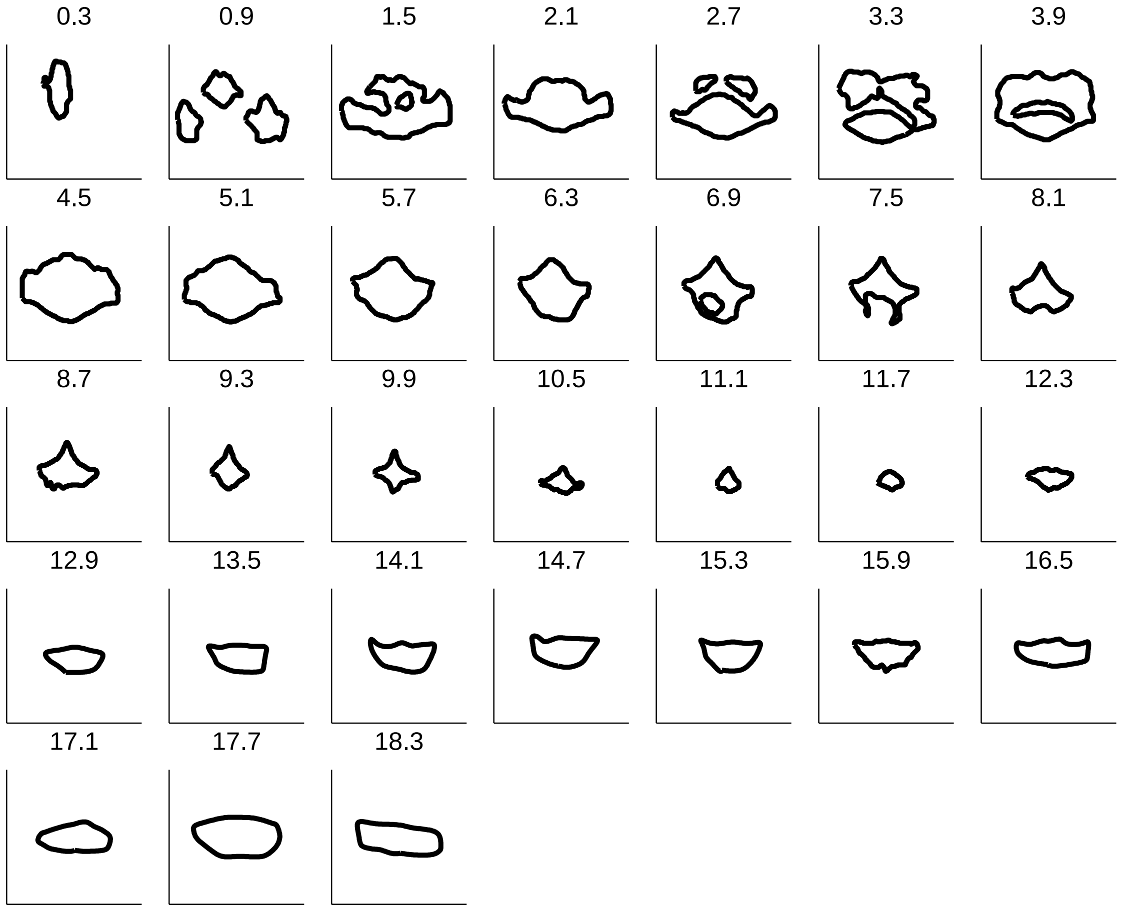

F2 vs. Constriction Degree
Gradient (Hz/mm)
Subjects
Correlation Coefficient
U = Unrounded (i/e)
R = Rounded (y/ø)
C
T
H
M
P
S
0
−5
−10
−15
−20
−25
−30
−35
−40
−45
−50
1
0.8
0.6
0.4
0.2
−0.2
−0.4
−0.6
−0.8
−1

To better understand why these differences occur, the following steps are being followed:

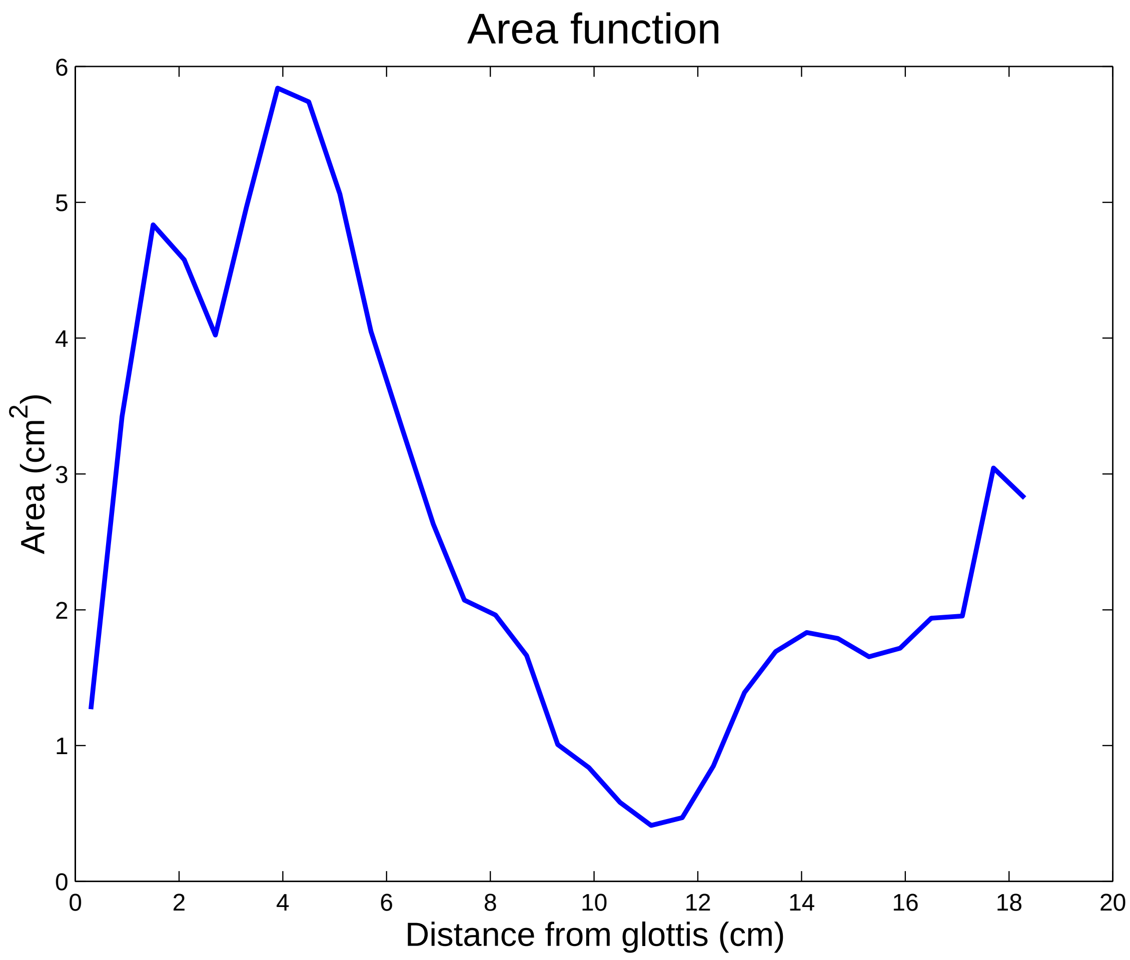
1. Collect axial, coronal and sagittal NMRI scans of each subject for each vowel
2. Derive area functions
3. Detailed comparison of area functions between subjects
4. Manipulate the area functions in a manner consistent with the patterns found in the EMMA data
5. Resynthesize the acoustics from the area functions
6. Compare empirically-derived and resynthesized articulatory-acoustic relations
7. If necessary, further manipulation of the area functions to improve the match obtained at step 6.



Mid-sagittal NMRI slice for subject T, vowel /e:/, with superimposition of grid used to extract vocal-tract areas



Vocal-tract cross-sections extracted from axial and coronal scans; distance from glottis indicated in cm.


Area function
Area (cm^2)
Distance from glottis (cm)
0
1
2
3
4
5
6
0
2
4
6
8
10
12
14
16
18
20

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