Control of larynx height in vowel production revisited: A real-time MRI study

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1. Background

Previous studies of larynx height: Typically a small number of subjects, and conflicting findings

On the one hand: A robust finding that larynx position is lowest for /u/

On the other hand: Moisik et al. propose an inverse relationship between larynx height and vowel height – a compelling idea! See movie example 1 (S10_pate_lh_sound.mp4)

But the actual data for /a/ vs. /i/ is very messy.

Is the low larynx position for /u/ related to rounding or tongue-position?

Impossible to decide based on languages without front rounded vowels (e.g. /y/).

But very little data on these vowels ➔ German is a useful language

Wider Issues:

Lip protrusion and larynx lowering in rounded vowels: complementary or compensatory?

➔ individual patterns of co-variation

Interspeaker variability in general:

Appears to be substantial. Can it be related e.g. to vocal-tract anatomy?

2. Method

Realtime MRI: 1.4 x 1.4mm in-plane pixel resolution, 50.05 fps

30 (approx.) German speakers

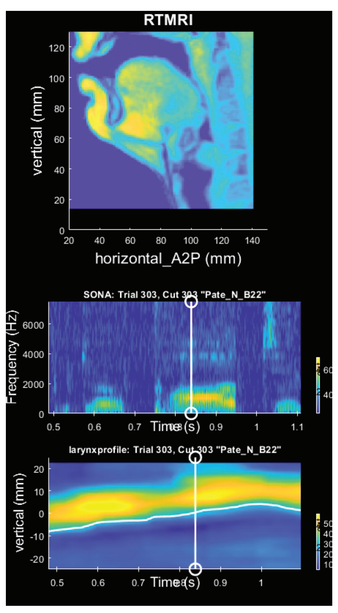
Corpus of approx. 350 utterances per speaker (target word embedded in carrier phrase)

Mainly designed to investigate nasal coarticulation in vowels.

Larynx height extracted at the midpoint of the lexically stressed vowel of each target word.

For each speaker approx. 10 tokens of each vowel category available for analysis

(number of tokens and consonant contexts not completely balanced over vowels).



Extraction of larynx height from raw MRI images

Reference image selected for each speaker from a schwa vowel in a constant segmental context.

Rotate this image so trachea and lower pharynx roughly vertical

Define a vertical strip (a few pixels wide) through the glottal region

For all images in each utterance:

Register the image to the reference image using the vertebral region adjacent to the larynx.

Extract the vertical strip and average over horizontal pixels.

Detect the lower edge of the larynx in this pixel profile through the glottis: Transition from low intensity (air) to high intensity (laryngeal tissue).

Figure shows image in target vowel /a:/ in “Pate”

Bottom panel shows pixel profile through glottis, time-aligned with spectrogram. White line shows extracted time-course of lower edge of larynx

Movie examples (mp4):

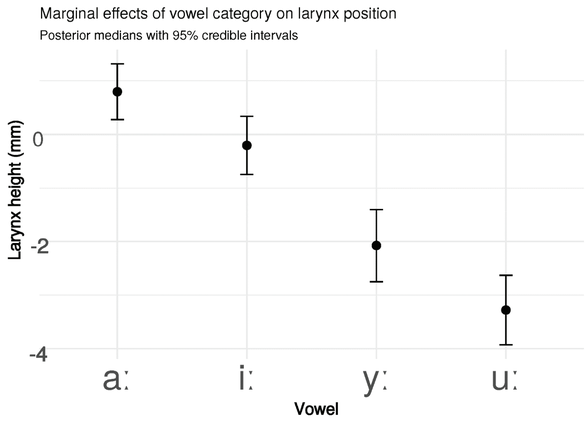
1: Hoole_33_Extra1 (S10, target vowel /a:/; shown here)
2: Hoole_33_Extra2 (S13, less larynx raising for /a:/ than S10)
3: Hoole_33_Extra3 (S13, massive lowering for rounded /o:/)

3. Results

Data were available for almost all German tense and lax vowels.

Here we focus on the tense vowels of key interest

(/e:/ and /o:/ were very similar to /i:/ and /u:/, respectively)



Main Findings

- Larynx somewhat higher for /a:/ than /i:/

  i.e. consistent with an inverse relationship between larynx height and vowel height.

BUT

- A weak effect compared to the effect of rounding, i.e. /i:/ clearly higher than /y:/

  /y:/ actually has slightly lower tongue height than /i:/ (clearly measurable in the MRI data) so here the effect of rounding must outweigh the tongue-height difference.

- /u:/ has slightly lower larynx than /y:/

  ➔In addition to rounding, tongue backness may contribute to the maximally low larynx position in /u:/

Further Findings

- Magnitude of vowel differences varies widely across speaker

  “Lazy larynx” vs. “Yoyo larynx”:

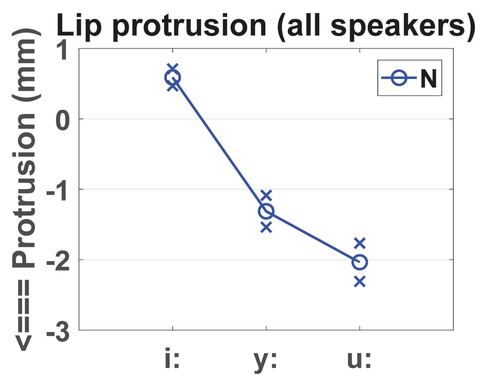
Q1: Can this be related to **vocal tract anatomy**?

NO!

Pharynx length showed no correlation with magnitude of vocalic larynx-height differences.

Same story for other VT features, e.g. ratio of pharynx length to oral cavity length.

Q2: Can this be related to coordination patterns between larynx height and other articulators, especially **lip protrusion**?



Lip protrusion (here upper lip) extracted automatically from MRI images using similar procedures to larynx height extraction.

Figure show means +/- 2.5 * SEM

- Striking similarity in larynx height and lip-protrusion pattern over /i:, y:, u:/
- Even very similar magnitude!

  /i:/-/u:/ difference approx. 3 mm in both cases
- /y:/ intermediate between /i:/ and /u:/ (but closer to /u:/)

4. Discussion: Larynx Height vs. Lip Protrusion

- Overall result confirms Wood’s proposal for advantageous articulatory-acoustic relationships in front rounded vowels:

  Moderate lip rounding and larynx lowering for /y/ (re. /u/) maintains the *lingual* constriction for /y/ in a region of acoustic stability.

- But do correlation patterns across speakers show any evidence for either complementary or compensatory coordination patterns between larynx and lips?

  For both /i-u/ (r=0.25) and /i-y/ (r=0.22) weak positive correlations between larynx height and lip protrusion.

➔ No evidence at all for *compensatory* (trade-off) adjustments.

But also no clear evidence for *complementary* adjustments

i.e. not obvious that speakers with e.g. strong protrusion for /y/ also show strong larynx lowering.

5. Outlook

Extend the search for co-variation strategies involving larynx height to include patterns of lingual articulation

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