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

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A mere 20 years after pointing out that MRI might be useful for expanding the range of subjects amenable to analysis of larynx height in speech (Hoole & Kroos, 1998) we now have first results for an extensive corpus of over 30 speakers of German recorded using state-of-the-art real-time MRI (1.4x1.4mm pixel resolution, 50.05 fps; Carignan et al., 2019).

Previous studies of larynx height have suffered perhaps even more than most articulatory investigations from small numbers of subjects, making conflicting findings very difficult to interpret (see Kirby & Sonderegger, 2018, on the issue of sample size in speech research). For example, while there is a robust finding that larynx position is lowest for /u/ (e.g. Ewan, 1979), it is much less clear whether larynx height for /a/ is typically higher than /i/, and thus how well the generalization proposed by Moisik et al. (2019a) of an inverse relationship between larynx height and vowel height actually holds (these authors (Moisik et al., 2019b) themselves note that the position of /i/ is often "unexpectedly high").

An investigation of German is particularly useful here, because analysis can be extended to front rounded vowels (see Riordan, 1977, for some data on a similar situation in French). Based on languages such as English it is impossible to ascertain whether a lower larynx position for /u/ than /i/, for example, represents an effect of rounding, or whether the effect is actually due to place of articulation of the vowel (velar vs. palatal).

Analysis of the complete set of tense and lax vowels in the corpus by means of Bayesian regression indicated that in addition to vowel height both rounding and front vs. back contributed relevant dimensions of variation in larynx height, whereas no specific contribution of tense vs. lax was found. Fig.1 shows the results for the key tense vowels /a, i, y, u/ (ordered from highest to lowest larynx position). The difference between /a/ and /i/ (about 1mm), while robust, was substantially smaller than that between /i/ and /u/ (about 3mm). The location of /y/ between /i/ and /u/ illustrates both the preference for lower larynx position in rounded vowels, but also the fact that place of articulation of the vowel is a separate additional factor. If F1 for high vowels is modelled as a Helmholtz resonance of constriction plus back cavity then lowering the larynx may be particularly useful for high back vowels to ensure a large back cavity volume and thus contribute to low F1 (cf. Moisik et al., 2019a). In addition, the result for /y/ indicates a further limit to a general inverse relationship between larynx height and vowel height: tongue position for /y/ is lower than for /i/ (the present MRI data clearly confirmed previous findings in this respect). Thus any possible (inverse) association between vowel height and larynx height must here be outweighed by the association with rounding.

In ongoing work we are currently further exploiting the fact that MRI gives a much more comprehensive picture of articulation than was available in previous studies of larynx height. The pervasive issue of inter-individual differences was also very marked in the present study. Some speakers vary larynx height by up to 1cm over vowels, some by only 1-2mm. The search for systematic patterns behind this can take at least two directions: Firstly, there is the possibility of a link with speaker anatomy, i.e. factors such as relative length of oral and pharyngeal cavities, or the amount of palatal doming. This information is straightforward to extract from the MRI data. Secondly, there is the issue of how larynx height is integrated into other articulatory manoeuvres. Front rounded vowels are once again a particularly interesting case in point in this respect. Wood (1986) has argued that larynx lowering for /y/ vs. /i/ is complementary to lip-protrusion in ensuring similar conditions for F2 stability for the rounded-unrounded cognates in

the face of possible perturbations of the common pre-palatal constriction. This would predict that speakers who protrude the lips strongly for /y/ also show more larynx lowering, whereas a possible alternative account, rejected by Wood (but see Riordan, 1977), would see larynx lowering as a compensatory mechanism to compensate for labial undershoot. However, the nature of the relationship between larynx-lowering and lip-protrusion has, in fact, never been tested across more than a few speakers. Analysis of the relevant labial and lingual data is nearly complete and will enable us to discuss the larynx-height results in terms of the very general issue of how apparently simple phonological oppositions such as rounding or vowel height map to a whole bundle of articulatory adjustments.

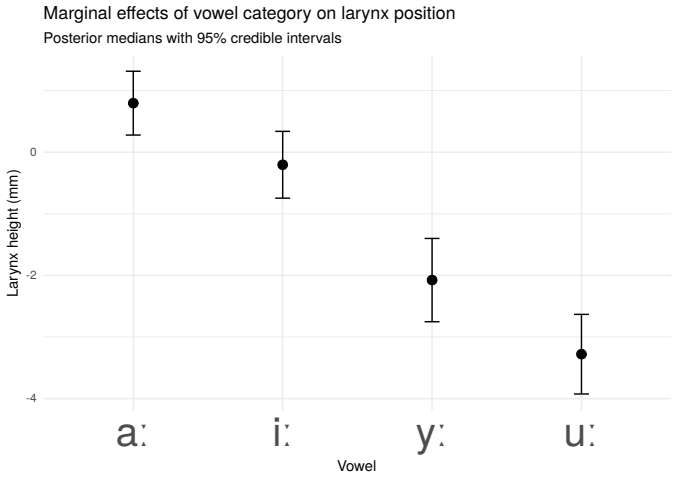

Fig. 1: Larynx height for four tense vowels. Values in mm centered on the mean over all vowels in the corpus. Measurements made at the acoustic mid-point of the vowel. n = 639, 363, 144 and 179 for /a, i, y, u/, respectively (the range of consonant contexts and hence the number of tokens was not completely balanced across vowels).

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