Tongue Adjustments in the Chest-Head Register Transition of Operatic Singers

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1 Introduction

The change in register from head to chest voice has been widely associated with laryngeal adjustments, including greater vocal fold adduction [1], longer glottal closed phase [2], and vocal fold thickening [3]. Comparatively little research has looked at supralaryngeal adjustments in singing register. Echternach and colleagues conducted a series of real-time MRI studies investigating the shape of the supraglottal vocal tract between registers [4, 5, 6], and reported that the tongue dorsum was more elevated and farther back in falsetto than in modal voicing for operatic singers [4]. Another study on classical singers and yodellers found the tongue dorsum to be more elevated for higher pitches [5]. These studies showed significant variation across individuals and different vowels [6]. All of these studies, however, measured the tongue at only two points: tongue dorsum/body height and pharynx width.

The present case study aims to provide a qualitative investigation into the specific tongue adjustments made during register shifts. In particular, we will report on overall changes in tongue contour using ultrasound imaging of the midsagittal plane. These measurements will be reported for one trained opera singer producing transitions between chest and head register, across six vowel categories.

2 Methods

2.1 Participants and Procedure

One mezzo-soprano opera singer, age 18, took part in this study and was recruited through word-of-mouth. The participant was enrolled in the opera program at UBC and had eight years of classical voice training, including private voice lessons and choral singing.

The participant was seated in an experiment chair with a stabilizing headrest to prevent unwanted head movement. An ultrasound probe was positioned to view a midsagittal section of the entire tongue length. Ultrasound videos were recorded while the participant sang an ascending and descending one-octave chromatic scale from G3-G4. These notes were chosen because the register transition fell roughly in the middle of the scale, providing ample data for both registers. A chromatic scale was chosen to have a consistent distance between notes to more accurately pinpoint the register transition. One scale was sung for each of the following vowels: /a, e, i, o, u/, and a rhotacized vowel /ɚ /.

2.2 Analysis

Audio was extracted from the ultrasound videos and manually annotated in Praat [7]. A script was then used to identify the midpoints of each note produced, and the corresponding ultrasound image frames were extracted using an R [8] script. These frames were run through EdgeTrak software [9] to find the x,y coordinates of the tongue contour in a two dimensional Cartesian spatial grid. We evaluated the register shape differences for each of the six vowels independently to avoid influence from vowel differences.

3 Results

Figure 1 plots the tongue contours of each token in the scale, for all six vowels, with the tongue tip on the right side. Results show that the presence of noticeable adjustments in tongue shape between registers for this singer is vowel-dependent. Specifically, vowels with constrictions in the inferior and posterior parts of the vocal tract contrast in tongue shape between head and chest voice. Low and mid-back vowels /a/ and /o/, as well as the rhotic vowel /ɚ/, show the most prominent adjustments. Conversely, the mid-front vowel /e/ exhibits minimal adjustments, and no observable adjustments are present for high vowels /i/ and /u/.

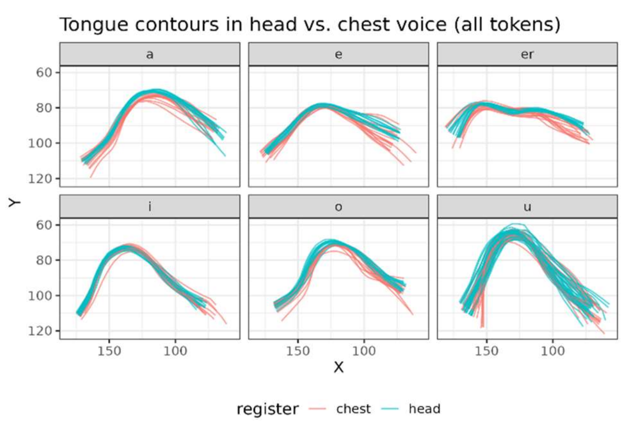

Figure 1. Individual tongue contours. Tokens sung in chest voice are in red, and tokens sung in head voice are in blue. /ɚ / is labeled "er" in this chart.

Figure 2 shows the smoothed contours of both registers for each of the six vowels, obtained via GAM method using ggplot's [10] `geom_smooth()` functionality. In general, for vowels where registers differ in tongue shape, the tongue dorsum is more elevated in head voice than in chest voice. The

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tongue root is also positioned higher in head voice than in chest voice, although this adjustment is to a lesser degree, as tongue root position shows some overlap between the registers for all vowels. The tongue tip is more elevated in head voice than chest voice for the vowels /o/, /e/, and /ɚ /, but shows no difference for /a/.

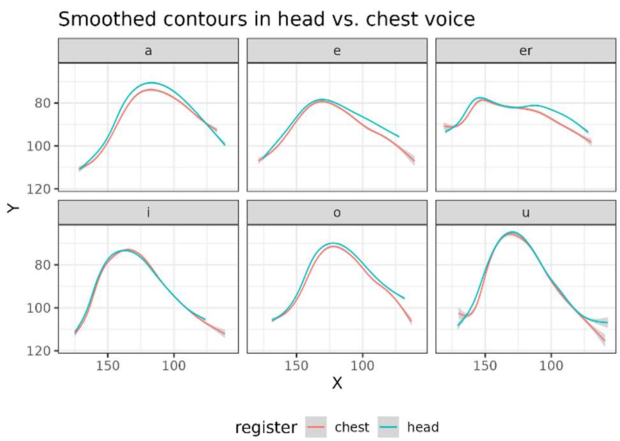

Figure 2. Smoothed contours. Tokens sung in chest voice are in red, and tokens sung in head voice are in blue. The shaded grey regions show the 95% confidence intervals. /ɚ / is labeled "er" in this chart.

4 Discussion

This qualitative case study provides a comprehensive examination of tongue adjustment during register transitions in operatic singing, focusing on tongue elevation and overall change in tongue contour. The obtained results demonstrate the role that supralaryngeal modifications play during vocal register transitions. These transformations in tongue contour emerged as being notably vowel dependent.

In alignment with the findings of Echternach et al. [4], we observed a distinctive variance in tongue position between the head and chest voices. Specifically, we identified an elevation in tongue positioning within the head register across all vowels.

Our analysis further underscores the influence of vowels on the adjustments made in tongue shape and position during register changes. Vowels with constrictions located closer to the posterior corner of the vocal tract exhibited greater differentiation in tongue shape between registers. This pattern indicates a potential link between the phonetic properties of a vowel and the degree of supralaryngeal adjustment during register transitions, meriting further investigation.

While this study offers valuable insights into the subject, we acknowledge the need for a larger participant pool for a more comprehensive analysis. The data presented here is from a single opera singer, limiting the generalizability of the findings. Future research should incorporate a larger participant pool and a wider range of voice types to explore the universality or specificity of these findings.

Acknowledgments

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