AN ULTRASOUND IMAGING STUDY OF THE TENSE-LAX DISTINCTION IN CANADIAN FRENCH VOWELS

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1. INTRODUCTION

Advanced tongue root (ATR) vowels are produced with significant tongue root advancement, creating a large pharyngeal resonant cavity that is not present during production of non-advanced vowels. Acoustically, this results in a lowered first formant (F1) for ATR vowels as compared to non-ATR vowels. This difference is most prominent among high vowels (Ladefoged and Maddieson, 1996). In terms of phonological features, advanced and non-advanced tongue root correspond to [+ATR] and [-ATR], respectively. These features are correlated with traditionally labelled 'tense' and 'lax' vowels in Germanic languages. Cross-linguistically, a number of gestural strategies are employed to create a distinction among so-called tense and lax vowels. In Igbo, these vowels differ only in tongue root position, while in Akan and Germanic languages such as English, they differ in both tongue root position and tongue body height (Ladefoged and Maddieson, 1996). A third possible method of contrasting tense and lax vowels is by varying tongue body height alone.

With respect to Canadian French (CF), there has been no articulatory evidence to support the hypothesis that tense and lax vowels are distinguished in a way similar to Igbo on the one hand, or Akan, English and German on the other. Acoustic evidence (Séguin, 2010) shows that tense high vowels in CF have a lower F1 than their lax counterparts. However, as mentioned above, a decrease in F1 could be caused by a number of lingual gestures, of which tongue root advancement is one possibility. Nonetheless, a prevalent assumption in literature that treats with the phonetic and phonological properties of tense and lax high vowels in Canadian French, especially with respect to harmony (Poliquin, 2006), is that these vowels are distinguished by tongue root position. More specifically, tense high vowels (/i y u/) are assumed to be articulated with an advanced tongue root while lax vowels ([ɪ ʏ ʊ]; allophonic variants of the tense vowel phonemes) are not. This assumption appears to be based on analogy with Germanic and West African languages and is not motivated by any experimental (articulatory) evidence. The purpose of this experiment is to determine which articulatory gestures are used to distinguish between tense and lax vowels using ultrasound imaging to directly measure tongue position during speech production of native speakers of CF. Findings from this study, based on data from one speaker, indicate that tense and lax high vowels are not produced with an advanced tongue root, but rather that tongue body height alone is used to distinguish between these vowels, which suggests that CF does not distinguish tense and lax vowels in the same way as Germanic or West African languages.

2. METHODS

Thirteen native speakers of various dialects of Canadian French (Québec French, Ontario French and Acadian) participated in this study, recruited in the Ottawa-Gatineau region through university classes and word of mouth. Due to the lack of normalization procedures for ultrasound data, the results of one participant (a female Québec French speaker from Gatineau) are discussed below.

Stimuli for this experiment consisted of mono- and disyllabic words containing tense and lax vowels elicited in final open syllables and final closed syllables, respectively. Words were produced in carrier sentences "Je dis…" and "Je dis … encore". Participants were seated in an optometry chair in a sound-proof booth in front of a computer display. Stimuli sentences were displayed on screen and participants advanced to the next sentence using a remote control. The ultrasound transducer was placed under the participant's chin to obtain a mid-sagittal tongue image, with a headrest and transducer placement used for head stabilization. Attached to the transducer and a pair of goggles worn by the participant were two wooden sticks, each painted with two white dots. These dots were later used to correct for head movement and place all ultrasound images on the same coordinate system using the Palatron algorithm (Mielke et al., 2005). Ultrasound and video were recorded at 30 frames per second using the Ultraspeech software (Hueber et al., 2008) on a Terason T3000 portable ultrasound machine. Audio was recorded throughout using a gooseneck microphone connected to a USBPre amplifier. Recordings were made using Audacity at a sampling rate of 44.1 kHz. Praat (Boersma, 2001) TextGrids for the resulting WAV files were created using the Penn Phonetics Forced Aligner (Yuan and Liberman, 2008). Acoustic measurements of high vowel formants were made at the midpoint of each vowel using a Praat script. Ultrasound and video images were superposed using a Python script. Tongue surface contours were subsequently traced in Palatoglossatron (Baker, 2005). Statistical differences in tongue position were examined using a smoothing spline ANOVA (Davidson, 2006; Gu, 2002) for pairwise comparisons in R.

3. RESULTS

Acoustic analysis results echo those of Séguin (2010); tense high vowels are produced with a significantly ($p<.001$) lower F1 than their lax counterparts (see Table 1). No significant difference in F2 was found between any tense-lax vowel pair. The results of the articulatory analysis are shown in Figure 1, in the form of tongue surface contour comparisons for each tense-lax pair. The dotted lines represent the 95% Bayesian confidence intervals.

Significant differences in tongue position occur where these intervals do not overlap.

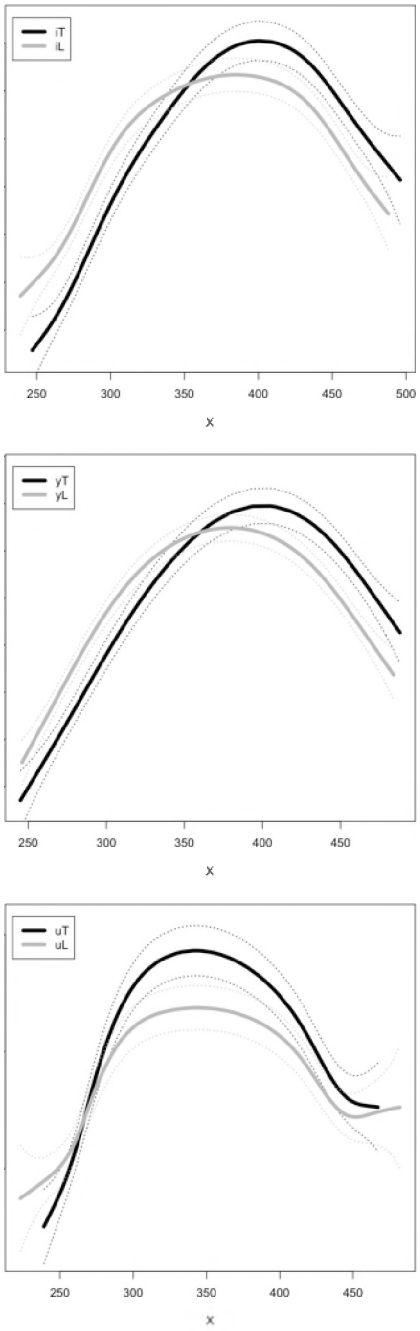

Figure 1. Tongue surface comparison plots for tense vs. lax high vowels (tense: black, lax: grey). From top: [i]-[ɪ], [y]-[Y], [u]-[U]

The comparisons of [i]-[ɪ] and [y]-[ʏ] reveal significant differences at the back of the tongue and at the anterior portion of the tongue body. The comparison of [u]-[ʊ] shows a significant difference in tongue position only in the tongue body. In all three comparisons, the tense vowel is produced with a higher tongue body. None of the comparisons shows evidence of a concavity at the tongue root that is typical of ATR vowels.

Table 1. Mean F1 values for tense and lax high vowels (Hz)

Phoneme	/i/	/y/	/u/
Tense	322.7	344.4	353.4
Lax	443.6	449.3	439.1

4. DISCUSSION AND CONCLUSIONS

This paper presented evidence that contradicts the assumption that tense vowels in CF are articulated with an advanced tongue root. The results indicated instead that tense and lax high vowels are distinguished by tongue body height alone. These findings contribute to our knowledge of the typology of gestures used to distinguish between tense and lax vowels. Igbo makes this distinction using tongue root position, while Akan, German and English employ tongue root position and tongue body height. CF resorts to a third strategy; using tongue body height alone to create a perceptible acoustic difference between two classes of high vowels. These results also have implications for phonological analyses of high vowels in CF, in particular motivating a reanalysis of laxing harmony that does not crucially rely on the existence of a ±ATR contrast among high vowels.

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