GESTURAL REDUCTION AND SOUND CHANGE: AN ULTRASOUND STUDY

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ABSTRACT

The magnitude of the tongue tip gesture in laterals in /VlC/ sequences produced by 8 American English speakers was measured with ultrasound imaging. Gestural reduction was found for pre-labial and pre-velar contexts relative to alveolar contexts. Also, for some speakers, reduction was greater for high-frequency than for low-frequency words. These patterns are tentatively interpreted as contributing to the initiation and lexical diffusion of sound changes involving /l/ vocalization.

Keywords: ultrasound, laterals, word frequency, gestural reduction, sound change

1. INTRODUCTION

This work studies the effects of phonetic context and word frequency on gestural reduction in laterals in American English. The broader aim of the work is to relate the articulatory patterns of gestural reduction to the initiation and lexical diffusion of sound changes involving lenition or loss of coda laterals.

Patterns of sound change show that, while laterals in many languages are produced with two lingual constrictions, one anterior and one dorsal, historically these laterals may lose their anterior constriction and be vocalized to /w/ or a back rounded vowel. Of particular interest here is that coda laterals are preferentially vocalized in pre-labial and pre-dorsal contexts, compared to pre-coronal contexts, as found, for example, in the history of the Romance languages [14] and in some varieties of English [1, 6, 7].

Articulatory measures of tongue position and movement in laterals produced by non-vocalizing speakers are suggestive of the phonetic source of place conditioning in historical vocalization (see also [13]). Even for speakers who do not produce perceptually vocalized laterals, the tongue tip gesture is less likely to reach its target in velar and labial contexts than in alveolar contexts. Giles & Moll's [4] cinefluorographic data showed that their American English speakers always achieved tongue tip contact with the alveolar ridge for coda laterals in coronal contexts (e.g., *melt*), but only variably achieved contact in pre-labial (*help*) and pre-velar (*elk*) contexts. Similar place-conditioned gestural reduction has been found for EPG measures of the dark /l/ productions of Majorcan Catalan speakers [13].

We investigated whether the magnitude of the tongue tip gesture in coda /lC/ clusters is conditioned not only by place of articulation of C, but also by the frequency of the word containing the /lC/ cluster. Lenitions and deletions are more common in high- than in low-frequency words as shown, for example, for English final /t d/ deletion [2] and schwa reduction [10]. Greater lenition in high-frequency words—a phenomenon presumably due to practiced, efficient speech—is argued to contribute to the spread of an ongoing change through the lexicon [2, 11]. Our work asks whether word frequency effects emerge not only in large-scale corpus analyses, but also in articulatory measures of gestural magnitude in the productions of individual speakers, similar to reduced gestural magnitude found for casual or fast speech [4].

2. METHODS AND HYPOTHESES

Target /(C)(C)VlC/ stimuli were paired high- and low-frequency English words in which coda C was bilabial or velar; alveolar-final words were included for comparison (Table 1). Lemma frequency (CELEX) was determined for all eligible words, and stimuli were selected from the most frequent and least frequent third of all words. Filler CVC and CVCC words were added for a total of 40 stimuli. Ultrasound and acoustic data were recorded for 8 speakers of a non-vocalizing variety of American English. Speakers' tongue surfaces were imaged using a Zonare z.one mini system and a P4-1c transducer, and recorded digitally at 60 fps. The transducer was stabilized in relation to the head using an ultrasound stabilization helmet (Articulate Instruments). Speakers read 14 repetitions of each word set; midsagittal tongue contours of target and

comparison words from 10 repetitions per speaker were analyzed.

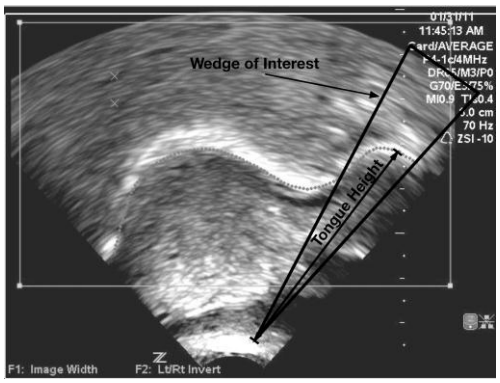
Table 1: Target and comparison stimuli. High = high frequency; Low = low frequency.

Labial - High	Labial - Low	Comparison
help	whelp	pelt
twelve	delve	weld
self, shelf	sylph	stealth, silt
film	helm	filled, held
Velar - High	**Velar - Low**	**Comparison**
milk	ilk	built
bulk	hulk	mulled

We hypothesized that speakers' lateral productions would exhibit place and word frequency effects such that (i) the tongue tip/blade (henceforth, tongue tip) gesture would be reduced in velar and labial contexts relative to alveolar contexts and (ii) reduction would be greater in high-frequency than in low-frequency words. We also expected (and found) the extent of reduction to be speaker-specific, gradient, and variable.

To test these hypotheses, tongue contours were traced using the software EdgeTrak [8]. For all contours of a given speaker, a single "wedge of interest" was defined for that speaker that included the tongue tip region. Tongue tip height (Figure 1) was determined for all lateral frames and maximal height within the lateral articulation was calculated. To generalize across speakers, height was normalized across all speakers by dividing individual height values by average height values for a given speaker.

Figure 1: Method of tongue tip height calculation

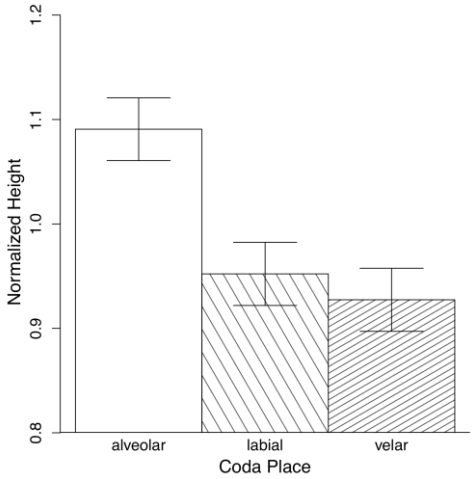


3. RESULTS

3.1. Place of articulation

The pooled (across-speaker) results in Figure 2 show that, as predicted, tongue tip position is higher in alveolar contexts than in labial or velar contexts [$F(2,14) = 13.39$, $p < .001$]. Tukey post-hoc comparisons show significant alveolar-labial and alveolar-velar differences ($p < .0001$), but the labial-velar difference is not significant ($p = .683$).

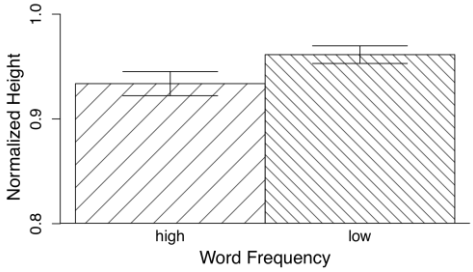
Figure 2: Tongue tip height by place of articulation



3.2. Word frequency

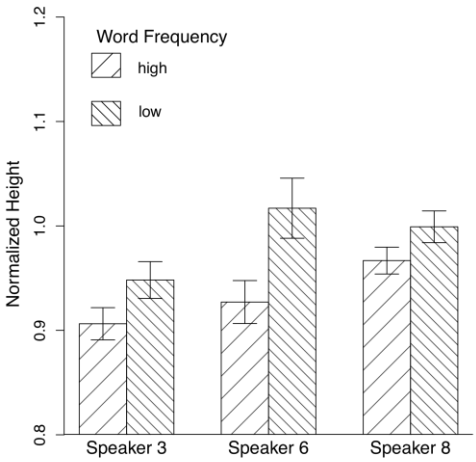
The pooled results in Figure 3 for high- and low-frequency target words (i.e., words ending in labials and velars) indicate a small effect of frequency in the predicted direction. A repeated measures ANOVA with subject as the error term showed only a trend for greater reduction of the tongue tip gesture in high- than in low-frequency words [$F(1,7) = 3.98$, $p < .09$]. With word pair as the error term, the effect of frequency was significant [$F(1,5) = 6.98$, $p < .05$].

Figure 3: Tongue tip height by word frequency



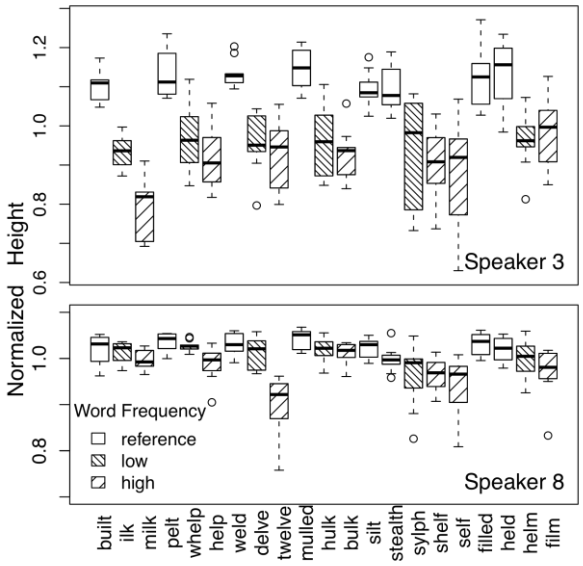
The outcome of the subject analysis points towards both a small effect and substantial across-speaker variation. Separate ANOVAs conducted for individual speakers showed tongue tip height to be significantly lower in high-frequency words for three speakers ($p < .025$, .0025, and .0004 for Speakers 3, 6, and 8, respectively); their results are in Figure 4. The productions of two additional speakers showed a trend in the predicted direction ($p < .10$), and the remaining three speakers' data showed no systematic frequency effect.

Figure 4: Tongue tip height by word frequency for speakers showing a significant frequency effect



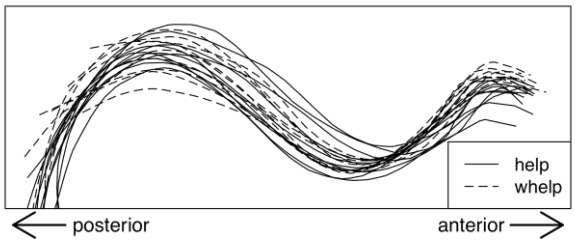
Unsurprisingly, even for speakers for whom frequency significantly contributes to reduction, there is substantial variation in reduction degree. These speaker-specific reduction patterns emerge when examining results by individual speakers and words, such as in Figure 5 for Speakers 3 and 8. [Figure 5 groups words so that corresponding reference (alveolar), low-, and high-frequency words are adjacent; see Table 1.] For Speaker 3, the magnitude of the alveolar gesture differs sharply for alveolar and non-alveolar contexts. Moreover, although none of Speaker 3's laterals were audibly vocalized, in some words (e.g, *milk*) they lacked a clear alveolar gesture.

Figure 5: Tongue tip height by word, Speakers 3 & 8



In comparison, Speaker 8 consistently produced alveolar gestures for laterals regardless of post-lateral coda place or word frequency. To illustrate, Figure 6 shows the tongue contours with the highest tongue tip for the 10 tokens each of *milk* and *ilk* produced by Speaker 8. All contours exhibit both lingual constrictions, although high-frequency *help* has the lowest tip contours and low-frequency *whelp* has the highest tip contours.

Figure 6: Tongue contours for *help*, *whelp*, Speaker 8



3.3. Other influences on gestural reduction

To date, our analyses have focused on the contributions of coda place and word frequency to gestural reduction in /(C)(C)VlC/ words. While we have not yet systematically studied other factors, at least three emerged in our preliminary analyses: preceding V, onset C, and individual words. For example, some speakers maintain a systematically higher tongue (dorsum and tip) position during the /l/ following a high vowel (*film*, *sylph*) than following a lower vowel (*helm*, *self*). Also for some speakers, onset sibilants influence the entire lateral tongue contour. Finally, individual words for particular speakers show evidence of especially reduced alveolar gestures (see Figure 5). A future step in this work will be to statistically model these sources of variance in alveolar gestures, and more generally in tongue contours, in laterals.

4. VOCALIZATION IN CASUAL SPEECH

To determine whether the frequency effect in our data is also present in more casual speech, we investigated /l/ vocalization in the Buckeye Corpus [12]. We extracted all words that end orthographically on <l> plus a consonant and that appear at least 10 times in the corpus. We noted for each token whether it was phonetically transcribed with [l], interpreting lack of transcribed [l] as evidence that the token was produced with audible vocalization. For each word, we calculated the proportion of utterances produced with vocalized /l/, and determined the linear correlation between these proportions and the frequency of the words in the corpus (log transformed at base 10). We found a strong positive correlation (r^2 = .28, p < .01): the more frequent the word is in the corpus,

the more likely it is to be produced with a vocalized /l/. The vocalization proportions range from 0 for infrequent words like *result* and *wild*, to .22 for the most frequent word *old*.

5. SUMMARY

Consistent with the literature on lateral articulation [4, 5, 13, 15], these data show that, even for speakers who produce most or all laterals in /VlC/ codas with a tongue tip gesture, that gesture is reduced in labial and velar contexts—contexts that do not themselves require a tongue tip gesture. We also predicted that laterals in high-frequency words would be produced with an especially reduced tongue tip gesture. This prediction was upheld for some, but not all, speakers, and the overall effect was quite small. Contributing to the small size of the effect may be our laboratory conditions. However, that high-frequency words may indeed involve greater reduction in laterals is supported by an analysis of conversational speech recordings from the Buckeye Corpus.

6. IMPLICATIONS FOR SOUND CHANGE

That labial and velar codas contribute to reduction of the tongue tip gesture in laterals mirrors the contribution of these same contexts to the historical development of /l/ vocalization in various languages. In this respect, our data reinforce the "closure undershoot" account of vocalization considered by Recasens & Espinosa [13]. The contribution of word frequency to reduction, present for some speakers, parallels the existing corpus-based literature demonstrating that, the more frequent the word, the more likely vowels and consonants in that word are to undergo lenition. We interpret these two influences, coda place and word frequency, as contributing to the initiation and lexical diffusion (respectively) of /l/ vocalization. Although we have not yet measured the acoustic effects of these gestural reductions, their degree in some cases is suggestive of perceptible effects which, within Pierrehumbert's [11] exemplar model of lenition and sound change, could result in increasingly reduced alveolar gestures over time.

We have not yet accounted for the lip rounding component of vocalization, as in the change from /l/ to /w/ (or /u/ or /o/). It is tempting to speculate that lip rounding might involve spread of the lip gesture from labial to non-labial contexts, but our study of the relevant historical patterns does not point toward greater or earlier vocalization in labial contexts. Alternatively, it may be that listeners-turned-speakers intentionally enhance the low F2 frequency of laterals that have a tongue dorsum but not a tongue tip gesture through the addition of lip rounding (consistent with [3]), or that they misinterpret laterals with low-frequency F2 as involving lip rounding (consistent with [9]).

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