LEXICAL EFFECTS ON ENGLISH VOWEL LARYNGEALIZATION

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ABSTRACT

It is known that lexical statistics can influence coarticulation. For example, more confusable words (i.e. those with a low frequency relative to their phonological neighbors) have been shown to exhibit more nasal and vowel-to-vowel coarticulation than less confusable words in English and French. In this paper, we give evidence that another type of coarticulation, laryngealized phonation on vowels preceding coda-stops in English, behaves similarly. Words with lower relative frequencies show more laryngealization on measures of non-modal phonation than words with higher relative frequencies.

Keywords: non-modal phonation, creak, laryngealization, coarticulation, relative frequency

1. INTRODUCTION

The goal of the present study is to determine whether English lexical statistics affect the degree of laryngealization, also called glottalization. In particular, the focus here is on laryngealization of a vowel preceding an unreleased laryngealized coda-stop.

1.1. English vowel laryngealization

English does not have a phonation contrast in vowels, but vowels can show non-modal phonation in certain segmental and prosodic conditions [11]. Laryngealized phonation is characterized by irregular pulses in voiced segments, and is often found in English vowels before laryngealized coda-stops, in particular before /p, t/ [10]. The segmental context of these codas has been shown to affect the rate of laryngealization. In particular, more frequent laryngealization has been found when the coda-stop is followed by a sonorant [10], but it can also occur when the stop is followed by an obstruent [6]. Such non-modal phonation can be thought of as coarticulation of a laryngealized (often unreleased) coda-stop onto the preceding vowel, and the focus of this paper is on this type of segmentally-derived laryngealization.

1.2. Lexical effects and coarticulation

Lexical statistics can influence speech production. It has been shown that higher frequency words exhibit more reduction [9]. Similarly, [15] found that the degree of neighborhood density could also predict vowel reduction. Words with mostly low frequency neighbors are produced with greater vowel reduction than those with higher frequency neighbors. This suggests that words with few or low-frequency neighbors may be ‘hypoarticulated,’ as in the hyper- and hypo-articulation model [7], to ease production.

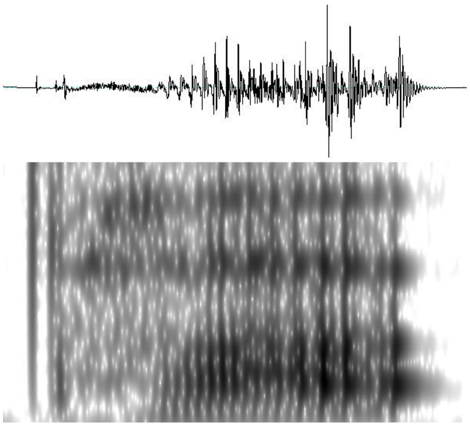
Coarticulation is often viewed as a form of hypoarticulation. However, such a view has been contested by [12], who found that more ‘confusable’ words (i.e., those with a lower relative frequency) in English and French exhibit more nasal and vowel-to-vowel coarticulation than less confusable words. [12], following claims by [4, 8], suggests instead that coarticulation is perceptually useful, in that listeners may use it to perceive confusable words more accurately.

The present study seeks to extend the findings of [12] to non-modal phonation coarticulation in English. If vowel laryngealization in English is the result of coarticulation from a following laryngealized coda-stop, then more vowel laryngealization should be found in harder, more confusable words.

2. METHOD

The target words for this study are 20 English monosyllabic words of form CVC, where the vowel is either /ɑ, æ/. The onset consists of an obstruent /p, t, k, b, d, g/ and the coda is either /p, t/. These codas are chosen because these codas are found to induce laryngealization on the preceding vowel. Figure 1 below shows the waveform and spectrogram of a sample token of *pot*. The second half of the vowel shows irregular spacing and amplitude of the glottal pulses, i.e. jitter and shimmer:

Figure 1: Sample waveform and spectrogram of *pot*, showing laryngealized phonation in the latter half of the vowel.



The confusability score for each word is calculated as in [12]. The confusability score takes into account both the frequency of the target word and the properties of its lexical neighbors. Confusability is based on the target's relative frequency (*R*), which is calculated by dividing the log frequency of the token by the sum of the log frequencies of the token and all its neighbors (*n*), shown in (1):

(1) $$R = \frac{\log freq_{word}}{\log freq_{word} + \sum_{i=1}^{n} \log freq_n}$$

Thus, a word will earn a low *R* score if it has many neighbors (especially those with high frequencies). A word with a high *R* score is one with few neighbors and/or one whose frequency is higher than its neighbors'. The frequencies are obtained from the $\text{SubtLex}_{\text{US}}$ corpus [3], and as in [10] the phonological neighbors are obtained from the CELEX database [1]. Pronunciations in the corpus are adjusted to reflect the pronunciation of Californian English. Neighbors in this study, as in [12], are defined by one phoneme addition, deletion, or substitution. The words in this study had relatively small *R* values, ranging from 0.012 to 0.066.

Twelve adult native English speakers, balanced for gender, were recorded in a sound booth. Each target word was uttered in the carrier phrase *Say the word a _______ for me*, and speakers were asked to repeat each sentence. No instructions for speaking style were given.

3. ANALYSIS AND RESULTS

The target words' vowels were segmented and labeled in Praat [2]. The onset and offset of clear first and second formants were used to delimit the vowel during which clear harmonic structure could be attained. The acoustic measures were obtained from VoiceSauce [14], which calculates the difference in amplitude between the first and second harmonic (H1*-H2*, corrected for vowel formants) and Harmonics-to-noise ratio (HNR, below 500 Hz). These measures were used because they have been found to differentiate laryngealized phonation from modal phonation in English, showing lower values for both measures during laryngealized phonation [5]. The values for both measures were normalized and averaged over thirds of the vowel's duration to see whether effects of relative frequency could be found over large portions of the vowel.

The results for each vowel third were then analyzed using a linear mixed-effects model with the *lmer* function in R, with the acoustic measure as the dependent variable and confusability (*R*) and speaker sex as fixed effects. Speaker and item were included as random effects. P-values were obtained using the *pvals.fnc* function in *lmer.*

For H1*-H2*, the results show no main effect of *R* in the first two thirds. However, in the final third, a significant main effect of *R* was found (p=0.042), with a higher value in *R* resulting in a greater estimated H1*-H2* value (i.e., less laryngealization):

Table 1: Results of the linear mixed-effects model for H1*-H2* in the final third.

H1*-H2*	Est. of *R*	Std. Error	T	P-value
Final third	26.58	13.03	2.04	0.04*

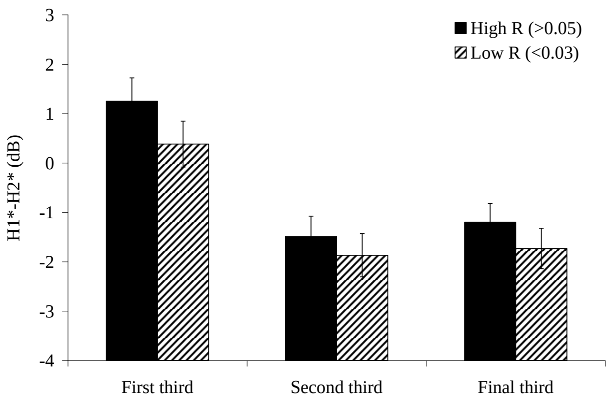
For HNR, a significant main effect of *R* was found at the final third, with a higher *R* value resulting in a greater estimated HNR (i.e., less laryngealization):

Table 2: Results of the linear mixed-effects model for HNR in the final third.

HNR	Est. of *R*	Std. Error	T	P-value
Final third	74.00	32.06	2.31	0.02*

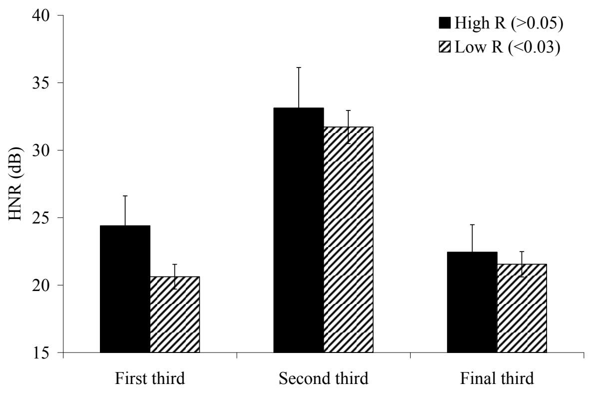
Thus, we interpret these findings as showing that more confusable words (those with a lower relative frequency or *R*) are more likely to have lower values of H1*-H2* and HNR. The lower values of these measures can be taken as evidence for greater degrees of laryngealization. Sample data are shown in the figures below to schematize this effect. In figure 2, the mean values of H1*-H2* by thirds are plotted for the words with the highest *R* in the sample (*R*>0.05) and for the words with the lowest *R* (*R*<0.03). The words with higher *R* also have higher values of H1*-H2* than the words with lower *R* values, suggesting the latter are more laryngealized.

Figure 2: Average value of H1*-H2* by thirds, for the words with the highest and lowest *R* values.



Similarly for HNR, the words with the lowest *R* values also have lower HNR values than words with the highest relative frequency:

Figure 3: Average value of HNR by thirds, for the words with the highest and lowest *R* values.



To see qualitatively where the effects of laryngealization diverge between the two *R* groups, we plotted time courses of each measure (averaged over vowel ninths) in Figures 4 and 5.

The differences in H1*-H2* between the two groups are concentrated in the first third and at the final two ninths. For HNR, the differences between the two *R* groups are mostly in the first two ninths. This cannot be due to onset effects, given that the two groups are balanced for onset type.

Figure 4: Average value of H1*-H2* by ninths, for the words with the highest and lowest *R* values.

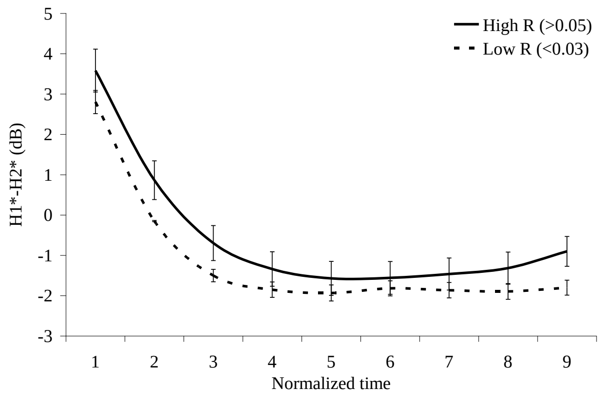
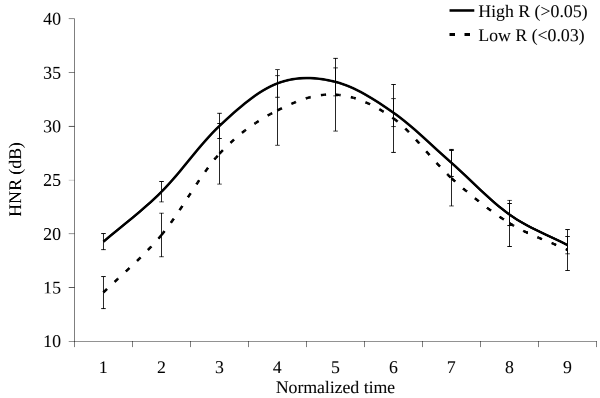


Figure 5: Average value of HNR by ninths, for the words with the highest and lowest *R* values.



Therefore, the time courses show that the effects of vowel laryngealization can be seen most clearly at the beginnings and ends of the vowels for these two subgroups, though there is a trend for more confusable words to have lower H1*-H2* and HNR values (thus, greater laryngealization) throughout the vowel's duration. When all the data are pooled together, as in Tables 1 and 2, the influence of R is only found in the final third, with more confusable words showing more laryngealization.

4. DISCUSSION

The results of the study indicate that, for the sample of words included, lower-*R* forms have more laryngealized phonation offsets than higher-*R* ones. Thus, more confusable words, i.e. those with more (high frequency) neighbors, are likely to show more coarticulation of laryngealized phonation than the less confusable words, supporting and extending the findings of [12]. If coarticulation aids the listener in retrieving segmental cues, then more confusable words, like those with lower *R* values here, should exhibit more laryngealized coarticulation. Indeed, it has been suggested that laryngealization can help cue the listener to the place of articulation of the following stop by amplifying the higher harmonics in the vowel [13]. Laryngealization associated with certain lexical tones in Mandarin and Cantonese has also been shown to improve tonal recognition [16]. Accordingly, laryngealization is in many ways beneficial, and so speakers may utter more laryngealized vowels in order to aid the listener in English.

This study, like that of [12], has implications for [7] hyper- and hypo-articulation. In this theory, coarticulation is viewed as a form of hypo-articulation, with coarticulation being a form of phonetic undershoot. However, the findings of [4, 8, 12], further supported by this study, show that coarticulation should be viewed as a useful source of phonetic knowledge.

5. CONCLUSION

This study provides evidence that laryngealized phonation on English vowels preceding coda-stops is stronger in more confusable words. Words with lower relative frequencies show lower values for H1*-H2* and Harmonics-to-noise ratio than words with higher relative frequencies. The fact that laryngealization may aid coda recognition suggests that speakers increase vowel laryngealization in more confusable words in order to help the listener. Further perceptual work would be useful in supporting the claim that laryngealization helps cue English listeners to the place of articulation of the following coda.

6. ACKNOWLEDGEMENTS

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