ARTICULATORY CONFLICT AND LARYNGEAL HEIGHT

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ABSTRACT

In cases of articulatory conflict, gestures involved in preserving phonemic distinctiveness are generally favored over gestures that do not. Here, an apparent exception to the phonemic distinctiveness preservation hypothesis is shown to in fact conform to it: in English, the larynx is lowered before voiced stops to maintain voicing distinctiveness, but the larynx is raised during high vowels, as a byproduct of pull from the tongue body. When a high vowel precedes a voiced consonant, the requirement of a lower larynx for consonant voicing should outweigh the higher larynx for the high vowel. However, available acoustic evidence runs counter to this prediction. New evidence from articulatory data of laryngeal movements is presented to show that laryngeal lowering, in fact, persists during vowels before voiced consonants even when the vowel is high. Thus the distinctiveness preservation hypothesis is supported.

Keywords: gestural conflict, laryngeal height

1. INTRODUCTION

Articulatory conflict occurs when phonetic manifestation of two adjacent segments requires antagonistic gestural achievements. For example, Gick and Wilson [5] describe two cases in English involving high vowels and liquids. In words such as "feel" and "peel," the high front position of the tongue body for /i/ is at odds with the following /l/, which requires a retracted tongue body. Likewise, in words such as "pool" and "fool," the tongue body height for the vowel /u/ is at odds with the lower, retracted tongue body of the liquid.

Articulatory conflict is resolved in one of several ways. Antagonistic gestures may be separated by an interval of time, so that both gestures are fully realized without any conflict [4]. This strategy describes the case of "feel" and "peel," where speakers in some dialects of English apparently insert an epenthetic schwa between the vowel and liquid [5]. The "space" created by the schwa allows both /i/ and /l/ to be fully realized. Alternatively, one or both antagonistic gestures may be augmented, so that conflict is reduced or eliminated altogether [4]. This strategy describes the case of "pool" and "fool," where speakers in some dialects of English lower the vowel from [u] to [ʊ] [5]. Vowel lowering reduces the conflict with the low tongue body of the liquid.

In addition, a gesture involved in preserving phonemic identity of a segment appears to play a significant role in the resolution of articulatory conflicts. For example, Russian exhibits phonemic contrast between palatalized and unpalatalized stops. In cases where a stop occurs between two vowels, the tongue body gestures for the vowels would be in conflict with the tongue body gesture for the intervening stop. Influence of the vowel gestures on the consonant gesture could therefore undermine preserving the phonemic identity of palatalization. However, Keating [8] notes that Russian in fact resists vowel-to-vowel tongue body coarticulation and argues that it does so precisely to preserve phonemic identity of the stop. In contrast, it is argued that English allows such coarticulation because consonant palatalization is not phonemic [8].

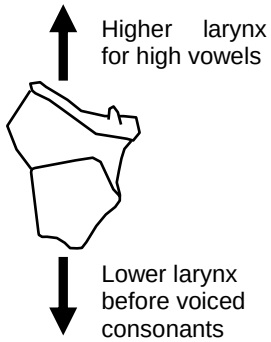
The universality of the phonemic preservation hypothesis is yet unclear. For one, much of the literature on articulatory conflict addresses cases where phonemic distinctiveness for both segments is at stake. The issue is to find cases like Russian where phonemic identity of only one segment is at stake. In addition, much of the recent work on articulatory conflict address cases involving the tongue body only. The issue is whether coordination of other gestural achievements is equally responsive to phonemic preservation.

In this paper, a case of articulatory conflict is reported involving the position of the larynx during certain VC sequences. Acoustic data alone would suggest laryngeal movement is not at all responsive to the phonemic preservation hypothesis. However, articulatory data support an alternative view, where laryngeal gestures involved in preserving distinctiveness trump those that do not.

2. LARYNGEAL HEIGHT

In English, the larynx is LOWER for voiced consonants than for voiceless consonants as an active attempt to maintain subglottal air pressure [4, 12]. At the same time, the larynx is HIGHER for high vowels than for low vowels as a side effect of the tongue body "pulling" the larynx upward [10].

Figure 1: Height of the larynx as a function of context.



Thus, the position of the larynx for a high vowel (raised larynx) is at odds with its position before a voiced consonant (lowered larynx).

3. ISSUE

The laryngeal position before the voiced consonant is an active gesture involved in preserving voicing distinctiveness, whereas the laryngeal position for the high vowel is a byproduct of the tongue body gesture and not involved in preserving distinctiveness. Consistent with the phonemic preservation hypothesis, the lower larynx for voicing should outweigh the side effect of pulling from the high vowel. Supporting this theory, Hillenbrand, et al. [6] report that F1 of vowels is lower before voiced than voiceless consonants, an effect they attribute to a lower larynx for the voiced consonant that carries over to the vowel. However, Hillenbrand et al. report that the F1 lowering effect is strongest for /ɪ/, /æ/, and /ɛ/ but "negligible" for the high front tense vowel /i/ (755). This would support the view that the pulling effect on the larynx from the high tense vowel outweighs the lowering effect to maintain consonant voicing, contra the distinctiveness preservation hypothesis.

At issue, then, is whether the acoustic facts reported in Hillenbrand et al. [6] match the actual movement of the larynx. An experiment was designed to test this issue directly.

4. EXPERIMENT

4.1. Setup

One female and three male speakers of American English participated in the study (ages 25, 22, 31, and 34). Two are from suburban Chicago, one is from suburban Milwaukee, Wisconsin, and one is from rural Iowa.

Participants read a set of ten monosyllables containing /i,ɪ,e,ɛ,æ/ before /t,d/ (e.g. /pit/, /pid/, /pɪt/, and so on). They read the syllables three times each in the sentence frame *Say ___ again*.

Acoustic recordings were made using a Sure SM10A-CM head worn microphone. Recordings were digitized at 44 kHz. Articulatory recordings were made using a Sonosite Titan portable ultrasound unit with a C11 8-5 MHz transducer set to image at a depth up to 8.2 cm. The ultrasound unit and microphone were both attached to inputs of a Data Corporation DM-300 digital video recorder, which recorded the display of the ultrasound in synch with the acoustic signal. Data was saved on the hard drive of the recorder as a .dv file and transferred to a desktop computer for analysis.

Audio data were extracted from the video file and analyzed using Praat [2]. Images from the ultrasound video were extracted and analyzed using the angle measurement tool in ImageJ [11].

Data from two of the participants were discarded due to poor resolution of the ultrasound images.

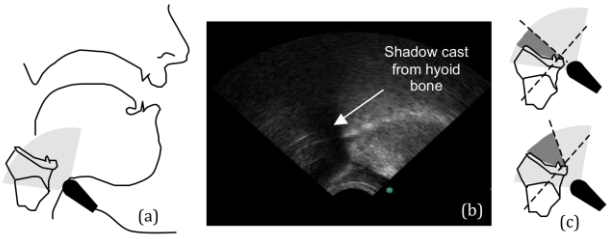
4.2. Acoustic measurements

Acoustic measurements were obtained of F1 at 20%, 50%, and 70% of vowel duration.

4.3. Articulatory measurements

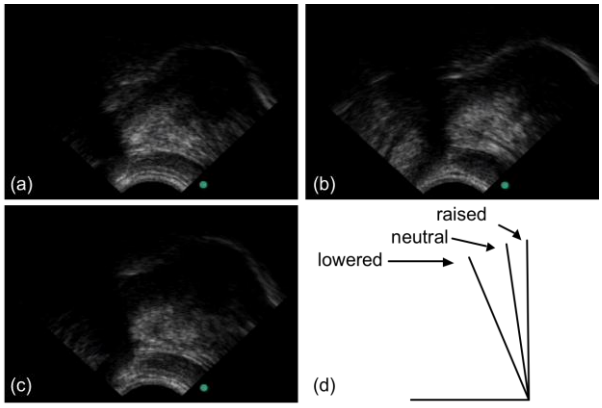
Laryngeal height was determined indirectly by measuring movement of the hyoid bone, which is known to couple with movement of the larynx [9, 10]. The hyoid bone casts a shadow from an ultrasound probe, and the higher the angle of the shadow cast, one can infer the higher the position of the larynx. Angles of the shadow cast by the hyoid bone were obtained at 20%, 50%, and 70% of vowel duration as well as at the point of closure of the coda consonant.

Figure 2: Holding procedure for ultrasound recording.



The method of measuring laryngeal movement was validated in Bauer [1]. A trained phonetician said /dada/ with a raised larynx, neutral setting, and lowered larynx. Angles of the shadow cast by the hyoid bone were obtained at the midpoint of the first vowel and compared across conditions.

Figure 3: Validation of measuring laryngeal movement, from Bauer [1].



The result conformed to the expected pattern: the hyoid bone cast the highest angle in the raised larynx condition, and the lowest angle in the lowered larynx condition

4.4. Results

Results from the study show that laryngeal lowering persists during vowels before voiced consonants even when the vowel is high. Thus the distinctiveness preservation hypothesis is supported.

4.4.1. Articulatory results

For both speakers, the angle of the hyoid bone shadow was generally lowest for all vowels before voice consonants at 70% vowel duration and during consonant closure than before voiceless consonants (Figures 4 and 5). In the figures, asterisks = /i/, squares = /ɪ/, triangles = /e/, circles = /ɛ/, and diamonds = /æ/. This result is consistent with the hypothesis that laryngeal lowering for voiced consonants outweighs any pull from higher vowels.

Figure 4: Articulatory results for Speaker 1.

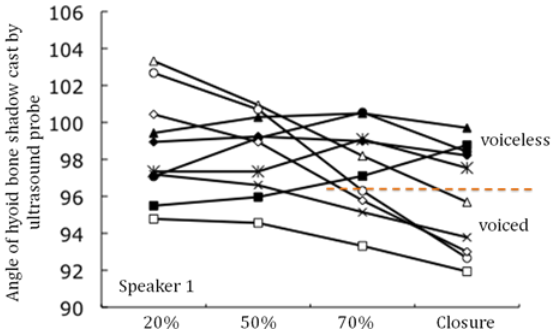
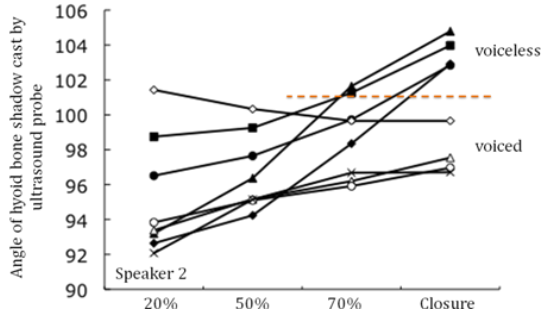


Figure 5: Articulatory results for Speaker 2.



There are some differences between Speakers 1 and 2, but these are not relevant to the issue at hand. The angle of the hyoid shadow at the beginning of vowels for Speaker 1 is consistently *higher* overall compared to the angle at the end of the vowel and at the point of consonant closure, whereas the angle for Speaker 2 is consistently *lower* overall compared to the angle at the end of the vowel and point of consonant closure. Such variation in laryngeal height across speakers has been observed elsewhere [7], and the pattern here is likely due to differences in the way Speakers 1 and 2 held the ultrasound probe.

Overall, articulatory results provides support for the claim that, in cases of articulatory conflict, gestures involved in preserving phonemic distinctiveness are favored over those that do not.

4.4.2. Acoustic results

Acoustic results generally follow those of Hillenbrand et al. Both speakers exhibit a lower F1 at the tail end of mid-lax and low vowels before voiced consonants, but the contrast in F1 is absent for mid tense and high vowels.

For both speakers, F1 is lower before voiced consonants than voiceless consonants at the tail end (at 70% vowel duration) of the low and mid-

lax vowels /ɛ,æ/ but there is no difference in F1 before voiced versus voiceless consonants at the tail end of mid-tense and high vowels /i,ɪ,e/ (Figures 6 and 7).

Figure 6: Acoustic results for Speaker 1.

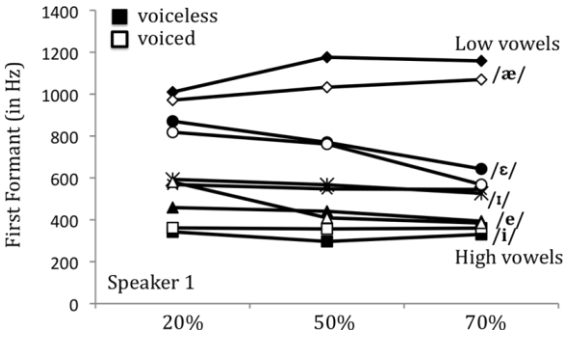
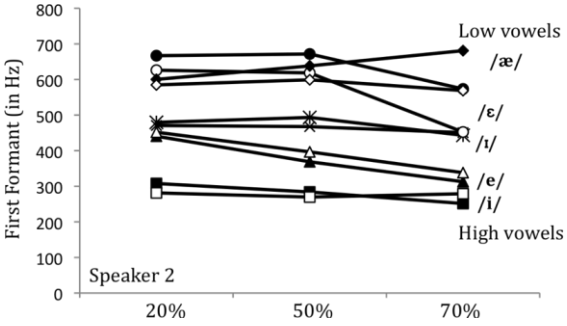


Figure 7: Acoustic results for Speaker 2.



The acoustic results would appear to show laryngeal lowering to maintain voicing is blocked in high vowels but not in low vowels. However, the articulatory data already show that no such blocking occurs. Instead, the results indicate an acoustic-articulatory mismatch: Laryngeal lowering persists even though there is no acoustic evidence of it.

This acoustic-articulatory mismatch might be attributable to the large back cavity for high front vowels. The volume of the cavity could render any laryngeal movement to have no significant effect on F1.

A larger back cavity is associated with a lower F1. The size of the back cavity can be increased by forward movement of the tongue body or by downward displacement of the larynx. In the case of low vowels, the tongue body is retracted, leaving a smaller cavity. In the case of high vowels, the tongue body is forward, leaving a larger cavity. Further downward displacement of the larynx for a voiced consonant would add to the volume of the back cavity. For high vowels, this additional volume may be insignificant and not affect F1, whereas for lower vowels, the additional volume may be sufficient to lead to a noticeably lower F1.

5. CONCLUSION

Results from the study show that laryngeal lowering persists during vowels before voiced consonants even when the vowel is high. The result would suggest that the laryngeal lowering gesture to maintain subglottal air pressure for voicing outweighs any conflicting laryngeal raising effect from the tongue body during the production of higher vowels. Thus the distinctiveness preservation hypothesis is supported.

6. REFERENCES

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