The Effect of Stress on Consonantal Loci

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Abstract

The report presented in this paper concerns with the extent to which stress affects the locus of the consonant in V#CV sequences. Two stress positions [$\acute{V}_1CV_2$and $V_1C\acute{V}_2$] were studied. Locus equations coefficients were used to determine the degree to which carryover of vocalic gestures from a stressed segment impact the onset of C in the following unstressed segment, and the extent to which the presence of stress on V_2 reflects on the locus of C. The results show that stress is a significant factor under the two conditions. In both test cases, $V_{2,}$ regardless of stress, closely affects the consonantal locus than V_1. However, the degree of V_2's influence on C is significantly reduced when V_1 is stressed, and enhanced when V_2 is stressed.

1. Introduction

Coproduction, the most widely embraced view of coarticulation and pivotal to many other studies [1, & 2], was originally formulated by Öhman's [3] numerical model. The core notion is gestural overlap. Öhman's original concept of coproduction postulated a diphthongal V_1 to V_2 movement, with a superimposed intervocalic gesture. Consequently, the lingual movement of V_1 lingers after the release of the consonant (carry-over coarticulation), and the articulatory movement for V_2 is initiated before consonantal closure (anticipatory coarticulation).

Evidence of vowel-to-vowel coarticulation abounds in the literature. Acoustic [4] studies have shown that articulatory influence of one vowel could extend into the midpoint of another spanning across intervening consonants. Both electropalatographic, and kinematic studies [5, 6] provide additional evidence showing that the influence of a vowel extends into the steady state of the transconsonantal vowel. Furthermore, Fowler [7] and Whalen [8] also reveal that gestural overlap extends across syllable boundary and transcends the syllable.

However, there are factors that have been found to affect the extent to which one segment can influence another. Recasens [5] proposes mutual compatibility of gestures for segments as a factor constraining the extent to which segments impact one another. While Öhman [3] points to the requirement imposed on the tongue body by the consonantal system of the language in question as a limiting factor, Fowler [9] among others, suggests that consonants offer certain degrees of intrinsic resistance to coarticulation. When the tongue is the main articulator for both the stop and vowel in a CV sequence, such a stop does not allow the vowel to pull the tongue far away from the consonant's characteristic locus of constriction [9]. Other factors that have been cited in the literature include the vowel system of the language, speaking rate and stress [10, 6].

This study addresses specifically, the effect that vowel stress has on the locus of an intervocalic consonant. The preliminary report presented in this paper is from an ongoing study that focuses on this issue. The aim of the study is to understand to what extent coarticulation is reactive to prosodic influences.

1.2 Prosody and coarticulation

Prosodic influence on syllables is well known. According to Munhall [6] stressed syllables are less susceptible to coarticulation than unstressed syllables. Also, de Jong [11] and Cho [12] show that vowels of English in prosodically strong position resist blending with neighbouring segments. In V_1CV_2 sequences, where V_1 is stressed, coarticulatory effect extends from V_1 to V_2, but when both vowels are stressed, there will be no coarticulatory effects between both vowels [3]. Lindblom [10] demonstrated that "vowels occurring in weakly stressed syllables are articulated with less 'efforts' and adjustment of the vocal organs that leads to their modification and reduction," Fowler [13] attributes this to the fact that stressed vowels are pre-eminent in speech production. They conscript the services of the articulators at the expense of unstressed

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segments to maintain their prominence. Thus, vowel in unstressed syllable is expected to be malleable while stressed vowels should not only resist blending but, strongly influence unstressed adjacent segments.

The present study examines the above conclusion with respect to how the onset of the consonant might be affected by varying positions of stress.

1.3 Research hypothesis

The acoustic consequence of gestural overlap is observable at the CV boundary. This is premised on the anticipatory articulatory movement for the postconsonantal vowel being initiated simultaneously with that of the consonant. Krull [14] and Sussman, et al., [15] using locus equations (LE) suggest that there is a linear relationship between F2midpoint of the vowel and F2 at the onset of CV. The slope of the regression line varies as a function of place of articulation and is conceptualised as quantifying the extent of CV coarticulation. The closer the slope value is to 1 the greater the F2onset of the consonant changes as a direct and linear function of the following vowel, and the closer to zero, the more independent of V_2, C is. In such case there is lesser degree of CV coarticulation.

Based on the above, it is reasonable to expect;

(i) reduced degree of CV coarticulation when V_1 is stressed, because of the lingering effect of V_1;

(ii) greater F2 coarticulatory effects, as a consequence of anticipatory movement caused by an upcoming stressed segment. Essentially, the movement towards V_2 is already in place during the consonant's occlusion.

2. Method

2.1 Test Materials

The speech material consists of carrier sentences in English, within which the test words [V#CV] are embedded. The tokens were chosen so that the stressed collocations are contiguous to the test consonants. The sentences were designed as follows:

Six vowels [i,æ,ʊ,o,ɑʲ,ɔ = V_1 stressed] were paired with 10 vowels [i, eʲ,ɛ, æ, ɑʲ, ʊ, o, ɔ, ʌ, aʷ= V_2unstressed]. To produce V_2 stressed, the 10 previously unstressed vowels were stressed, while the V_1s were not. For both conditions, ([b], [d], and [g]) were the intervocalic consonants. This summed to 120 sentences for each stop consonant. A subset of the test material exemplifying the different prosodic positions is given below:

<u>**V_1 stressed**</u>	<u>**V_2 stressed**</u>
I found two beads today.	
What, six beads?	*What two peaks?*
-No, **TWO** beads	-N0, two **BEADS**
What? Three beads?	*What? Two weeds?*
-No! **TWO** beads!	-No! two **BEADS!**

Stress was elicited by asking the speakers to emphasize the tokens written in capital as answer to follow up questions to their utterance.

2.2 Procedures

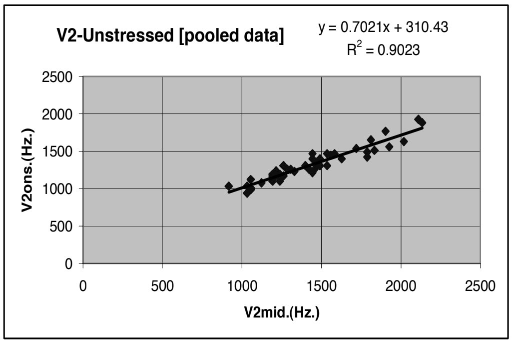
Two adult male speakers of American English were recorded in a sound treated room using a high quality microphone and a Marantz tape recorder. The recorded signals were sampled at 22kHz, digitized, and filtered using Macquirer. It was also used for all playbacks and measurement procedure.

2.3. Measurement.

Acoustic measurements were made from spectrograms. Measurements made for each token included: F2 V_1mid, V_1offset, F2V_2onset [last & first glottal pulse respectively.], F2V_2mid, and duration. All measurements followed Sussman, et al. [15]. Only the result for /b/ is presented here.

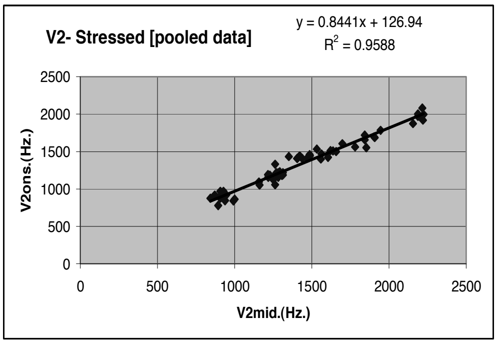
3. Results and Discussions

Graph 1a: Locus equations for/b/. The regression line equation shows slope and y intercept as indicated above each plot as well as R^2 value.



Graph 1b: Locus equations for/b/. The regression line equation show slope and y

intercept is indicated above each plot as well as R^2 value.



For V_2 stressed the slope value = 0.84; the intercept = 126; R^2 = 0.96; For V_1 stressed, the slope = 0.70, the intercept = 310, R^2= 0.90. The data point cluster more tightly when V_2 is stressed. Sussman, et al. [15] records a mean slope value = 0.87, intercept = 106.

Table1a, b: Linear Regression Analysis [pooled data].

Coefficients[a,b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant	149.930	37.303		4.019	.000
	V1OFF	.116	.023	.144	4.960	.000
	V2MID	.716	.023	.900	30.960	.000

a. Dependent Variable: V2ONS

b. STRESS = 1

With stress on V_1, there is a significant influence of V_1off on CVons $p< 0.001$; beta = .116 (unstandardized). The influence of V_2mid on CVons is also significant: $p< 0.0001$; beta = [.716].

Coefficients[a,b]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant	123.313	32.204		3.829	.000
	V1OFF	.031	.017	.038	1.832	.070
	V2MID	.824	.018	.971	46.876	.000

a. Dependent Variable: V2ONS

b. STRESS = 2

In 2b, stress is on V_2. The effect of V_1off is not significant at .05 level of alpha. The beta-value is .013. V_2mid is significant at $p< .0001$, beta = .824.

The unstandardized coefficients of the linear regression analysis in 2 show partial correlation between V_1off & V_2ons, and between V_2mid & V_2ons. The result e.g., in 2b says that with every unit increase in stressed V_2, *ceteris paribus*, V_2ons increases by .718. When V_2 is held constant, V_1 has zero effect on V_2ons.

Repeated measures analysis, tested at .05level of alpha, shows a significant mean difference $p< .0001$ for both speakers. In other words, they performed significantly different under the two test conditions.

The difference between F2ons and F2mid is another metric that captures the extent of CV coarticulation. A smaller difference points to a greater degree of coarticulation since the vowel gesture imposes itself more strongly on the consonantal gesture. Subtracting F2ons from F2mid produces a mean value of 114.12Hz.[V_1 stressed] and 90.58Hz.[V_2 stressed].

The results presented above for /b/ suggest that V_2 stress allows V_2 to closely influence the onset of the preceding stop. When the stressed segment precedes the intervocalic consonant, CV bonding is not broken, but is significantly attenuated. In light of the above results, it seems reasonable to suggest that when V_1 is stressed, less of the lingual gesture for V_2 is completed before the release of the stop occlusion, thereby resulting in lesser extent of CV coarticulation [16]. F2(Hz.) at CV boundary, that captures the locus of C, deviates from its target value, F2(Hz.)V_2mid. On the other hand, with V_2 stressed, anticipatory effect causes more of the tongue motion towards V_2 to be completed prior to release of occlusion. This raises the F2 at CV boundary, and it closely approximates V_2mid (greater coarticulation).

The above result is limited to /b/ because it is hoped that a bilabial stop provides a more stringent test for the effect of stress on the locus of C as evidenced by F2 measurements. With the lips as the primary articulators, the tongue is unencumbered, and can freely coarticulate with flanking segments.

4. Conclusion

The main question addressed in this paper concerns with how stress affects the locus of the consonant in V#CV sequences. It was shown that the locus of an intervocalic consonant is affected depending on the positioning of stress. When stress precedes the consonant (V#CV), the offset of V_1 impacts on the onset of V_2, thereby attenuating the extent of the affinity that would have otherwise obtained between C and V_2. This is shown by smaller slope value. However, when stress is on V_2, a greater degree of CV coarticulation results. The slope value in such

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case nearly approaches 1, and the locus of C (F2 at CV boundary) deviates minimally from that of V_2mid.

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