CV COARTICULATION IN YORUBA - A TONAL LANGUAGE

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ABSTRACT

The combinatorial interaction of suprasegmental and contextually induced segmental variations has been shown to produce independent coarticulatory effects. This study extended the locus equation (LE) methodology for the first time to a tonal language, Yoruba, in order to document how variations in tone might interact with CV coarticulation and to understand the patterning of its 4 voiced stops. Tonal variation did not produce significant alterations to F2onset values and hence does not serve as a phonetic factor leading to coarticulatory variation. LEs did show distinct categorical patterning for the voiced labio-velar stop /gb/ in Yoruba.

Keywords: locus equations, coarticulation, tone, voiced labio-velar stop

1. INTRODUCTION

Both segmental and prosodic/stylistic factors can affect anticipatory CV coarticulation. Emphatic stress expands vowel space in the F1*F2 plane, and rapid (reduced) speech shrinks vowel space. These imposed alterations have recently been shown to have independent and opposite effects on CV coarticulation (decreasing it in the case of emphasis, and increasing it in rapid speech). These effects were separated from vowel-context induced influences [1, 9].

Tone has received a good deal of attention in the literature with respect to its nature [3], its role in sound change and its phonology. Many studies have also focused on the interaction of consonants with tone. For instance, voiced and voiceless consonants have been shown to affect the F0 of the upcoming vowel depending on its tone [5]. However, less examined and unclear is the manner in which variations in tone affect the interaction between the segments of the tone bearing CV syllable.

As part of a larger project, this study examined the interaction between C+V segments in Yoruba to test whether tone differences affect the degree of coarticulation across stop place as indexed by LE slopes. The locus equation [12] has proven to be a reliable and useful phonetic metric for quantifying the extent of CV dependencies and in providing a much needed lawful orderliness to the acoustic representations of stop consonants produced across a wide variety of vowel contexts.

LEs are linear regression fits to scatterplots of coordinates representing, separately for each consonantal category, all F2 transition onsets, plotted on the y-axis, in relation to mid-vowel frequencies plotted on the x-axis [8, 12]. Consistently, these scatterplots yield tight clustering of data points around a highly linear regression line. LE slopes value ranges from 0 to 1, i.e., minimum to maximum CV coarticulation [6]. LE slopes and y-intercepts have been shown to be effective predictors of stop place of articulation with 100% correct categorization [8, 11].

Many studies have probed the usefulness of LEs. They have shown sensitivity to emphatic stress [9]) and tempo changes [1], as well as assessing the adequacy of coarticulatory theories [4]. LEs have received cross linguistic validations [13], and have been documented to capture language-specific patterns of coarticulation [3].

Motivational to this study was the finding that emphatic stress significantly affected the F2 onset values of stops in C+ V sequences [8]. Results showed that the F2onsets of [dV & gV] under emphasis were higher than their predicted non-emphatic correlates. Given that tone has prosodic properties somewhat similar to stress [7], it is reasonable to ask if tonal variations might also yield analogous coarticulatory effects.

Yoruba is a Niger-Congo language spoken primarily in western Nigeria. Of interest to this study are its seven vowels [i, e, ɛ, ɑ, o, ɔ, ʊ]; four voiced stops; b, d, g and gb (labial-velar stop), and its three lexical-level tones: mid, low and high. The mid tone is also called neutral tone and is often undesignated by any tonal mark. It has also been identified as the equivalent of stress-accent, perhaps may thus behave like prosody [5, 8]. The low tone is depicted by the grave accent and high tone by acute accent. Due to phonological constraints, the study focused only on mid and low tones. The research questions were: (1) Are CV-low tone segments less susceptible to anticipatory coarticulatory effects relative to mid-tone CVs?, and, (2) Do LEs categorically separate voiced labio-velar stop from other stops?

2. METHODOLOGY

2.1. Speech sample and elicitation of data

Meaningful nouns with different tonal properties were embedded within VCV sequences and elicited from native speakers of Yoruba. The test material consisted of V_1CV_2 sequences paired against $\grave{V}_1C\grave{V}_2$ that were produced in citation form. V_1 and V_2 are same. Six vowels were chosen to maximally exploit Yoruba acoustic space, these are [i, e, ɛ, ɑ, o, ɔ]. The medial consonants were /b d g & gb/. Examples of the tokens are:

[aba]raméjì vs. [àbà]ráméjì

òd[odo] vs [òdò]dó

g[idi]gidi vs. g[ìdì]gìdì,

[egbé] vs. [egbè].

For [gbV] tokens only the pairings were different. V_1 was always mid tone, while V_2 was varied between high and mid tone. The items in brackets were the focus of investigation.

Five adult male native speakers of Yoruba, all students at the University of Ibadan, participated in this study. Each subject produced a total of 72 tokens [$6V_1$ * 4C *3 repetitions].

2.2. Recording & measurement procedures

Subjects were recorded in a non-sound treated room using a uni-directional microphone (RCA RP3503) directly into a Dell laptop using Praat. The recorded signals were sampled at 22 kHz, digitized, and filtered using Praat [2], which was also used for all acoustic display and measurements.

Acoustic measurements were made from wide band spectrograms. F2 & F1 values were obtained for V_1 & V_2mid, V_1offset, and V_2onset following already established procedures [11, 12]. Pitch was obtained at the onset, mid and offset points of the pitch track generated by Praat. Inaccurately tracked tokens were removed, as well as tokens with wrongly realized tones.

3. RESULTS

3.1. Locus equations and /gb/

LE plots were obtained for each speaker and across the four stop place consonants. Table 3.1 presents the summary results of LE coefficients for /bdg/ and /gb/ respectively.

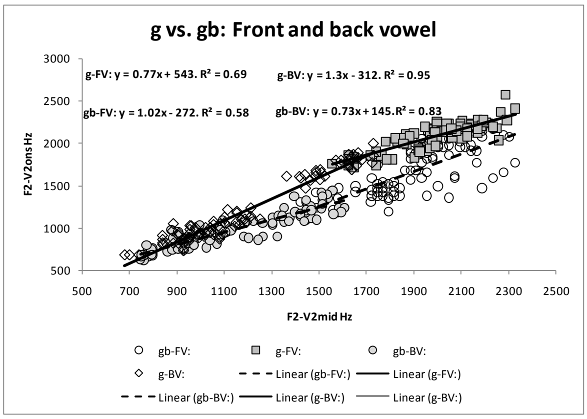
Table 3.1: Summary of LE slopes, intercepts, R^2 & SE for 5 subjects (Sb) and four stops b, d, g & gb.

Sb/VbV	Slope	y-intcp	R2	SE		*Sb/VbV*	Slope	y-intcp	R2	SE
KL	0.98	-95	0.97	65.4		*KL*	0.91	6	0.99	38
AD	0.85	49	0.98	47.4		*AD*	0.9	17	0.99	34
AW	0.88	35	0.95	68.8		*AW*	0.9	24	0.97	24
AR	0.95	72	0.96	74.8		*AR*	0.96	70	0.97	68
BL	0.85	80	0.98	57.2		*BL*	0.87	35	0.94	89
Mean	**0.9**	**28**	**0.97**	**62.7**			**0.91**	**30**	**0.97**	**51**
Sb/vdv	Slope	y-intcp	R2	SE		Sb/vdv	Slope	y-intcp	R2	SE
KL	0.61	704	0.94	58.7		*KL*	0.82	432	0.82	145
AD	0.61	674	0.98	36.7		*AD*	0.64	668	0.97	49
AW	0.5	961	96	40.4		*AW*	0.6	739	0.94	50
AR	0.4	1078	0.84	73.3		*AR*	0.42	1019	0.81	85
BL	0.47	983	0.88	76.7		*BL*	0.44	1073	0.75	105
Mean	**0.52**	**880**	**19.9**	**57.2**			**0.58**	**786**	**0.86**	87
Sb/vgv	Slope	y-intcp	R2	SE		Sb/vgv	Slope	y-intcp	R2	SE
KL	1.1	-65	0.95	91		*KL*	1.1	57	0.96	81
AD	1.1	-38	0.98	70		*AD*	1.1	75	0.99	50
AW	1.2	-179	0.98	64.1		*AW*	1.2	251	0.97	80
AR	1.1	-222	0.97	79		*AR*	1.2	328	0.96	103
BL	1.1	-193	0.97	79.2		*BL*	1.1	133	0.95	102
Mean	**1.12**	**-139.4**	**0.97**	**76.7**			**1.14**	**169**	**0.97**	**83**
Sb/vgbv	Slope	y-intcp	R2	SE		*Sb/vgbv*	Slope	y-intcp	R2	SE
KL	1.1	-264	0.89	146		*KL*	0.97	110	0.91	113
AD	0.97	-172	0.91	113		*AD*	1.1	293	0.95	92
AW	0.89	-8.9	0.87	127		*AW*	0.89	64	0.95	78
AR	0.97	-131	0.92	102		*AR*	0.87	61	0.89	121
BL	0.66	221	0.79	127		*BL*	0.68	191	0.89	79
Mean	**0.92**	**-71.0**	**0.88**	**123**			**0.90**	**144**	**0.92**	**97**

Table 3.1 is a summary of locus equation parameters. Overall, the table shows distinctive values for slopes and intercepts for /b d g gb/ for all subjects. The common ordering of LE slopes displayed for all subjects was: g > b/gb > d; this ordering is in line with previous LE studies. New, however, is the placement of /gb/ in the ordering. LEs effectively sorted stop place categories. The table also reveals that R2 accounted for the same amount of variation across the stops (>.90). The goodness of the fit to the data-points, as captured by standard error of measurements, was relatively low, except for the labial-velar stops which exceeded 100Hz.

Table 3.1 shows non-overlap across stops, except for /b/ and /gb/. To quantify the extent to which vowel place affected the coarticulation of /gb/, especially, given that /g/ has front/back vowel allophonic variants, LE parameters were further compared across allophonic groups for /g/ and /gb/. The result is presented in Figure 3.1.

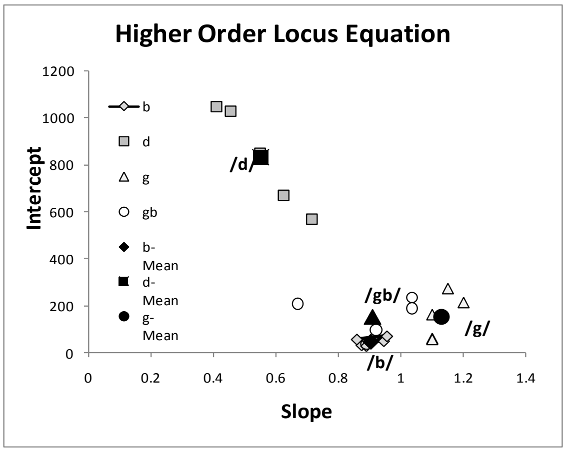
Figure 3.1: Locus equations for /g/ and /gb/ allophones as a function of front and back vowels.



Whereas allophonic variation for /g/ is characterized by two distinctively separate y-intercepts, this is not the case for /gb/ where the two allophonic groups were easily fit by one single regression line.

Figure 3.2 illustrates the contrastiveness of LE slopes and y-intercepts plotted for each speaker, for four stop place categories, and displayed in a derived higher order LE acoustic space. Slope and intercept were averaged across low and mid tone. The prominently bolded points are the means of the subjects for each stop place category.

Figure 3.2: Higher order locus equation slope and intercept computed based on F2ons = K*(V2mid) + C for all subjects, for b, d, g and gb.



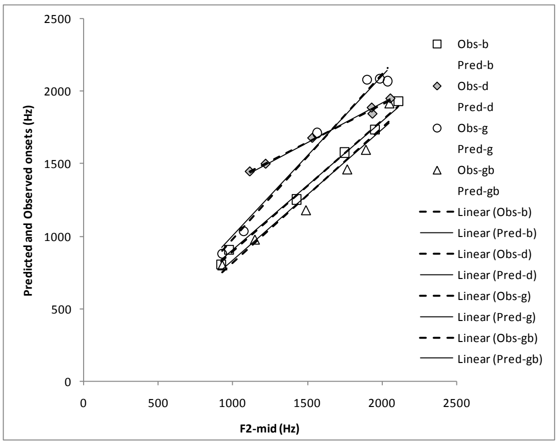
It also shows /gb/ as indicated by its mean to be closer to the bilabial stop than the velar stop in this categorical acoustic space.

2.1. Locus equations and tone

Statistical tests on the slope values, collapsed across subject and stops, showed no significant difference between the independent variable of mid vs. low tone. For [bV], neutral and mid tone slope values were 0.9; for [dV] segments, there was an insignificant 0.06 slope value difference; likewise, for [gV], mid and low tones both had similar slope values of 1.12. Essentially, vowel-context induced variation remained the sole factor determining the F2onset frequencies within each consonantal group. Unlike previous findings on prosody [1, 8], tone in Yoruba only functions at the lexical level.

A test for the equality of variances indicated that the variances of the two groups were not significant [t (46) =-0.00042. p= 0.999].

Figure 3.3: Deviation of observed F2 onsets from expected F2 onsets derived for all subjects and for b, d, g, & gb of Mid tone.



Figures 3.3, 3.4 and 3.5 were derived using a modified 2-D locus equation, first introduced in previous studies [1, 8]. 2-D LEs derive slope coefficients for both a preceding (carry-over) V1 context and a following (anticipatory) V2 context. The aim was to dissociate the probable effect of tone from vowel contextual variation. In Fig. 3.3 solid linear lines represent the predicted F2onsets. The six data points represent each vowel context for each stop. The difference in the LE slope between the predicted (solid line) and observed (dotted line) data points represents the degree of coarticulation that could be independently attributed to tone for each stop place. It can be seen that tone does not affect the extent of CV coarticulation as shown by the considerable overlaps between the linear lines.

Figures 3.4 & 3.5 shows the deviation of observed F2onsets from predicted F2onsets for each of the six vowels averaged across the five speakers and obtained for each of the four stops. The data points below or above the line of identity (zero) indicate that observed F2onsets were either lower or higher than the predicted, respectively.

Figure 3.4: Plot of observed C-onsets relative to predicted C-onsets for all subjects and for b, d, g, & gb for mid tone.

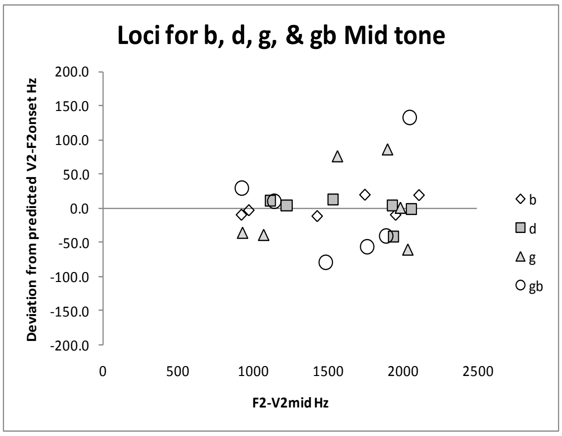
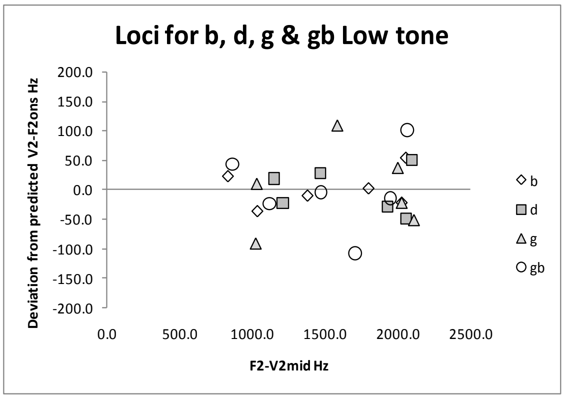


Figure 3.5: Plot of observed C-onsets relative to predicted C-onsets for all subjects and for b, d, g, & gb for low tone.



Whereas tokens in Figures 3.4 & 3.5 evince deviations from the line of identity, these differences when compared between low tone and mid tone are analogous and insignificant.

4. DISCUSSION AND CONCLUSION

This study investigated the possible effects of lexical tone differences in Yoruba on CV coarticulation in stop + vowel sequences. Unlike emphatic stress, which has a profound effect on V2's influence on F2 onset frequencies at release of stop closure, the lexical tone shifts in Yoruba do not exhibit such influences. Tonal variations simply affect formant frequency values, but in a normalized fashion similar to vowel F1*F2 changes due to vocal tract size differences. These changes do not influence categorical structure and hence are not reflected in LE parameters.

The acoustic analysis of labio-velar stops in Yoruba represents the first time this stop category has been compared to traditional labial, alveolar, velar stops. The most significant finding relates to the lack of allophonic clustering in /gb/ due to vowel frontness/backness. This stop more closely relates to labials.

5. ACKNOWLEDGEMENTS

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