St'át'imcets vowels and consonants: a phonetic study*

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1.0 Introduction

This paper presents an acoustic analysis of St'átimcets (St') vowel and consonant sequences, based on data from three female and one male speaker of the language. The paper has two goals. One is to describe and document the phonetic properties of St' vowels and their interaction with consonants. The other is to investigate the magnitude of coarticulation in St' CV and VC sequences, where place of articulation of C is varied systematically, and C is first pre-vocalic and then post-vocalic. CV and VC structures are of interest for several reasons. Of general interest is the directional strength of coarticulation, namely, whether a preceding consonant has more or less interaction with a vowel than a following consonant. Within Salish studies, this work speaks to the origin and synchronic analysis of the directional consonant-triggered harmonies that occur in several Interior Salish languages.

The paper is structured as follows. Section 2 outlines the methodolgy used in data collection and analysis. Section 3 presents the results of vowel analysis. Section 4 presents data on consonantal place of articulation as it is revealed in vowel structure, using locus equations. Section 5 concludes the paper.

2.0 Methods

The word list (Appendix A) is designed to elicit two sets of C_1VC_2 structures, each containing the stressed St' vowels /i, a, u, e / ('e' is schwa), in six consonantal contexts. In Set 1, C1 is sytematically varied across place of articulation to include /p, t, k, q, g, 7/. In set 2, C_2 is varied in the same way. In each set, the remaining C is restricted to a labial, coronal, velar or glottal stop. /p, t, k, q, g, 7/ are chosen as representatives of the six main places of articulation in the St' consonant inventory, (1). Thus, manner of articulation for the consonant of interest remains constant except for the pharyngeal glide /ʕ/, represented as 'g' in the orthography. (1) uses an orthography that differs from the IPA in the following ways: lh=ɬ, t'=t$^{ɬ'}$, c=x, cw=x^{W}, x=χ, xw=χ^{W}, y=j, y'=j', r=ɣ, r'=ɣ', g=ʕ, g'=ʕ', gw=ʕ^{W}, g'w=ʕ'^{W}.

(1) St'át'imcets consonant inventory

Lab	Coronal				Velar		Uvular		Pharyngeal		Glottal
p	t	ts			k	kw	q	qw			7
p'		ts'	t'		k'	k'w	q'	q'w			
		s	lh		c	cw	x	xw			h
m	n	z	l	y	r	w			g	gw	
m'	n'	z'	l'	y'	r'	w'			g'	g'w	

The word list contains two examples of each consonant and vowel combination. Four speakers were recorded saying the word list, with two repetitions of each token, for a total of four examples of each CV and VC combination per speaker. Recordings were made in a quiet room with a Marantz PMD 201 tape-recorder, a Shure SM57 microphone and metal tapes. Data were digitized at 12,500 Hz and analysed using the Kay CSL speech analysis system. Measurements include

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vowel duration as well as first (F1) and second (F2) formant values at vowel onset, vowel nucleus and vowel offset. Formant values were taken from FFT and LPC spectra at the vowel nucleus, but the mouse-controlled cursor was used to take readings from the first (or last) pulse of the vowel as it appeared on the displayed spectrogram. The vowel nucleus is defined as the point of deflection in the second formant, or the first formant if there is no deflection in the second formant. If there was no noticeable point of deflection in either formant, nucleus readings were taken at the temporal midpoint of the vowel.

3.0 Vowels

This section presents the results of formant analysis of St' vowels. Section 3.1 examines the overall vowel space using a traditional (F2,F1) plot. Section 3.2 looks at the effect of consonantal place of articulation on vowel production. Section 3.3 examines positional effects, that is, whether consonants have a different effect on a vowel when in C1 as opposed to C2 position. Unless otherwise noted, data from Set 1 and Set 2 are combined in the analyses which follow.

3.1 Overall Vowel space

Figure 1 plots the mean nucleus values (F1 and F2) for each vowel as produced by each speaker in all consonantal contexts. F2 is on the horizontal axis, F1 on the vertical. The graph includes the male speaker (BN) whose entire vowel space is shifted towards the upper right quadrant when compared with data from female speakers (BF, GN, RW). This reflects the lower formant values of male speech rather than any substantial difference in vowel quality. Plots of the raw data, one per speaker, are provided in Appendix B.

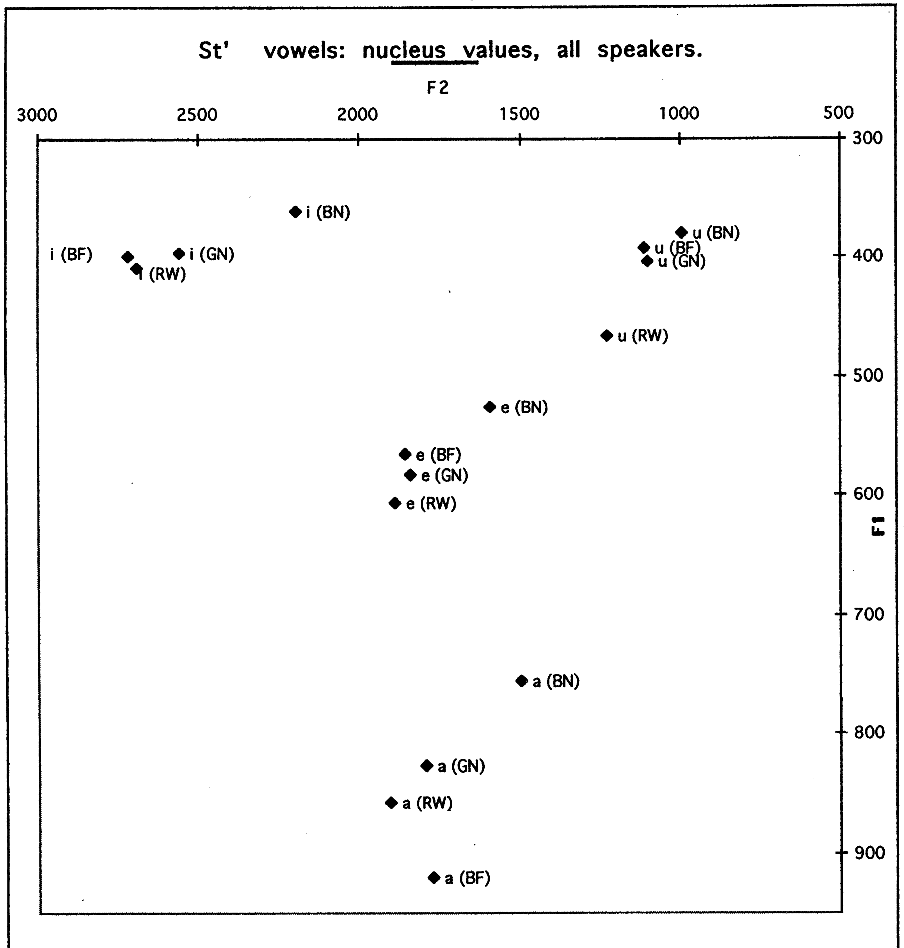


Figure 1: St' vowel space.

The St' vowel space is basically triangular, with the perimeter defined by /i, a, u/. /u/ is a back vowel, without any of the fronting found in some dialects of English. Schwa (/e/) occupies the center of the vowel space. Here /e/ appears to be a higher version of /a/, but its range is considerably greater. Duration also distinguishes /a/ and /e/, with /e/ by far the shortest vowel in the inventory.

Table 1: Vowel duration (seconds, with standard deviation)

	Speaker				
Vowel	BF	BN	GN	RW	AVG (sd)
i	.102 (.031)	.122 (.038)	.147 (.059)	.125 (.035)	.124 (.04)
a	.120 (.031)	.146 (.037)	.147 (.025)	.153 (.120)	.141 (.053)
u	.106 (.035)	.132 (.035)	.127 (.032)	.122 (.040)	.122 (.035)
e	.052 (.029)	.059 (.026)	.065 (.027)	.059 (.026)	.059 (.027)

3.2 How consonants affect vowels: a closer look

Local coarticulatory effects from consonants to vowels are frequently noted in the Interior Salish literature. In all languages effects from uvulars and pharyngeals are particulary noticeable, and for languages with schwa, an extensive range of coarticulatory effects is noted, with general agreement that the precise value of /e/ is entirely context dependent.

A general measure of consonant-induced vowel coarticulation is achieved by combining and averaging the formant values of the four vowels according to consonantal context. Thus, the averaged nucleus values of /i,a,u,e/ in the context of /p/, /i,a,u,e/ in the context of /t/, and so on, can be plotted. The result (Figures 2a, 2b) shows the effects of each cononantal place of articulation on overall vowel articulation.

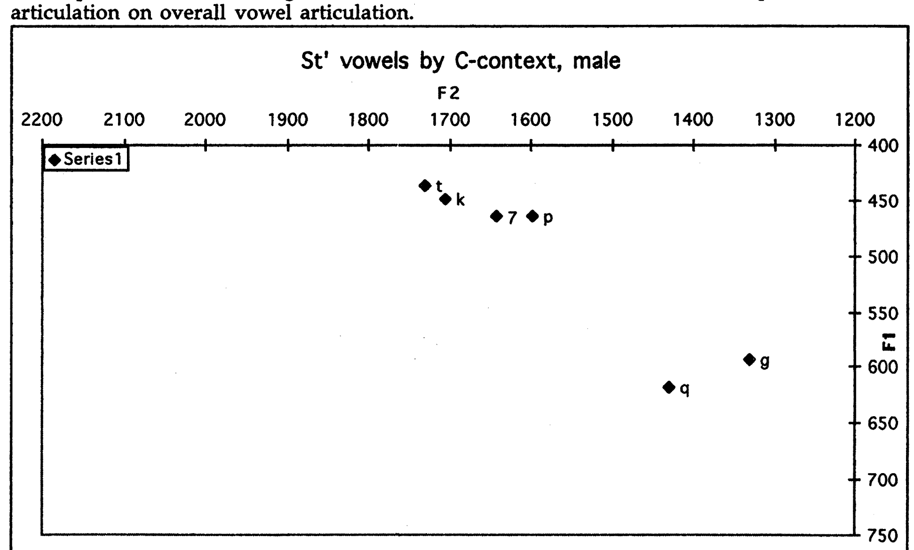


Figure 2a: St' vowels by consonantal context: male speaker (BN)

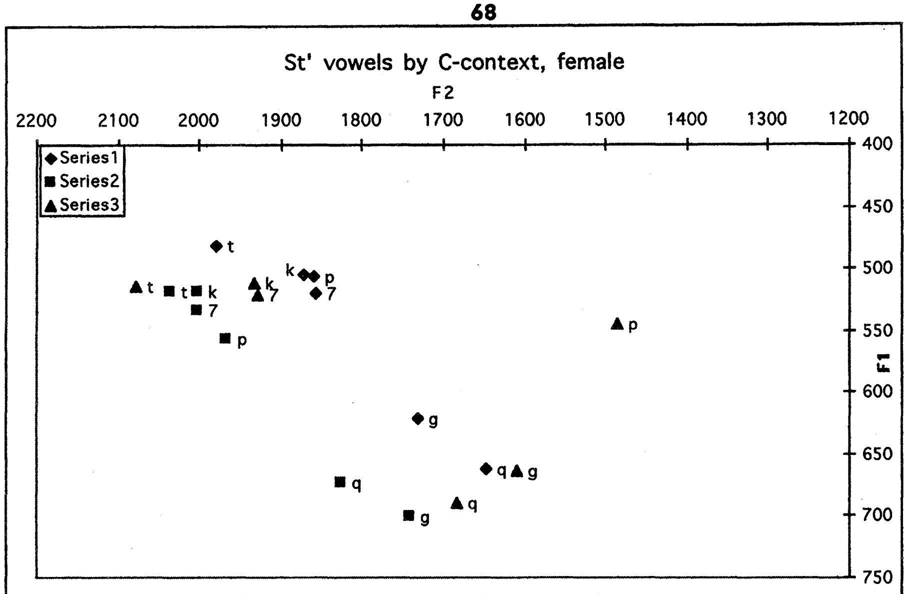
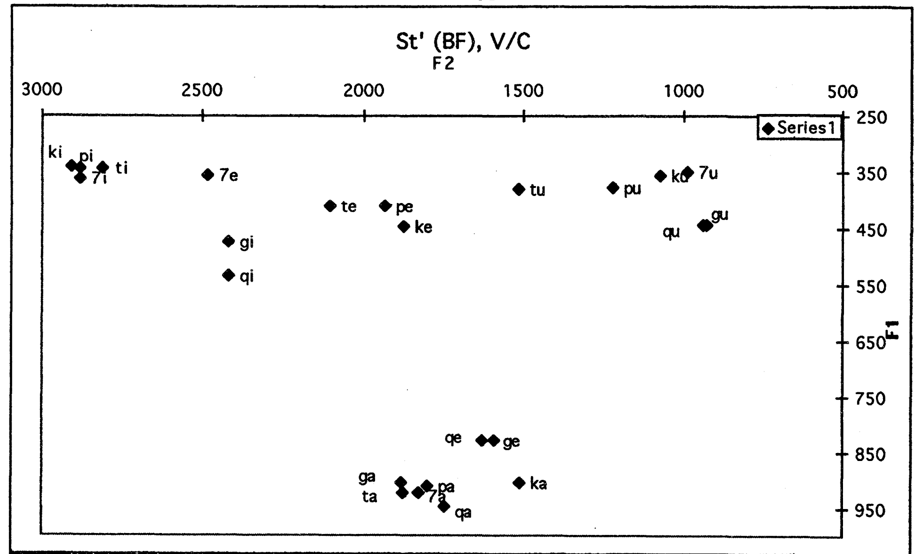


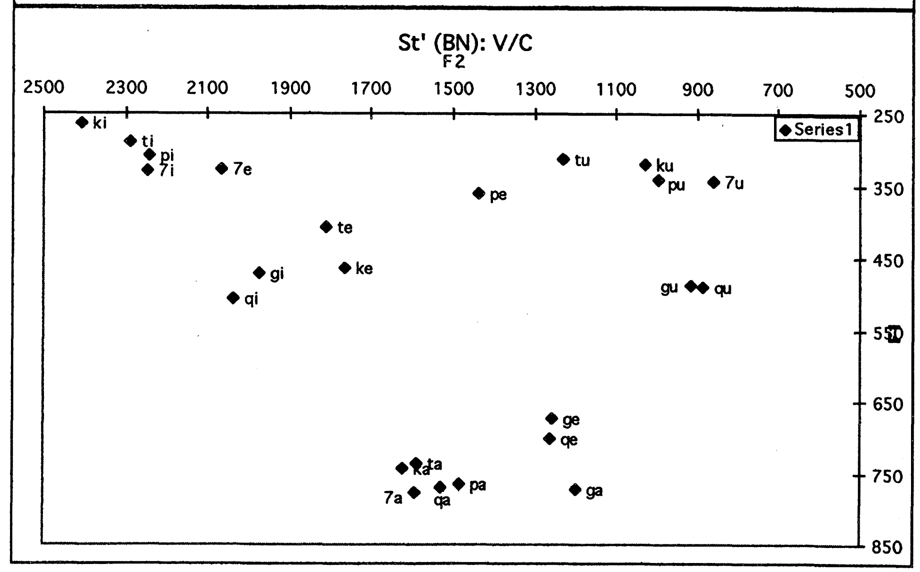
Figure 2b: St' vowels by consonantal context: female speakers (BF, GN, RW)

Since each point in Figures (2a, 2b) represents the combined and averaged F1 and F2 values of /i, a,u,e/ in a given consonantal context, the formant space is considerably reduced compared to Figure 1, which does not pool the vowel data in the same way. However, consonantal context clearly differentiates the averaged vowels. The most obvious division is between /p,t,k,7/ on the one hand and /q, g/ on the other. For all speakers, /q,g/ force vowels into the low, back area of the vowel chart (where F1 is high and F2 is low). Within the /q,g/ set there is variation as to which consonant conditions the most extreme form of this. A second consistent trend is the fronting effect of /t/, which always produces the most front average vowel quality (a raised F2). /k,p,7/, are not always systematically distinguished, although /7/ conditions the lowest average of the /p,t,k,7/ set in two speakers and /p/ tends to condition backing (lowered F2).

3.2.1 Consonant effects on individual vowels

Consonantal effects are more closely examined in Figure 4 where the average nucleus value of individual vowels is plotted according to consonantal context. Separate plots are given for each speaker.





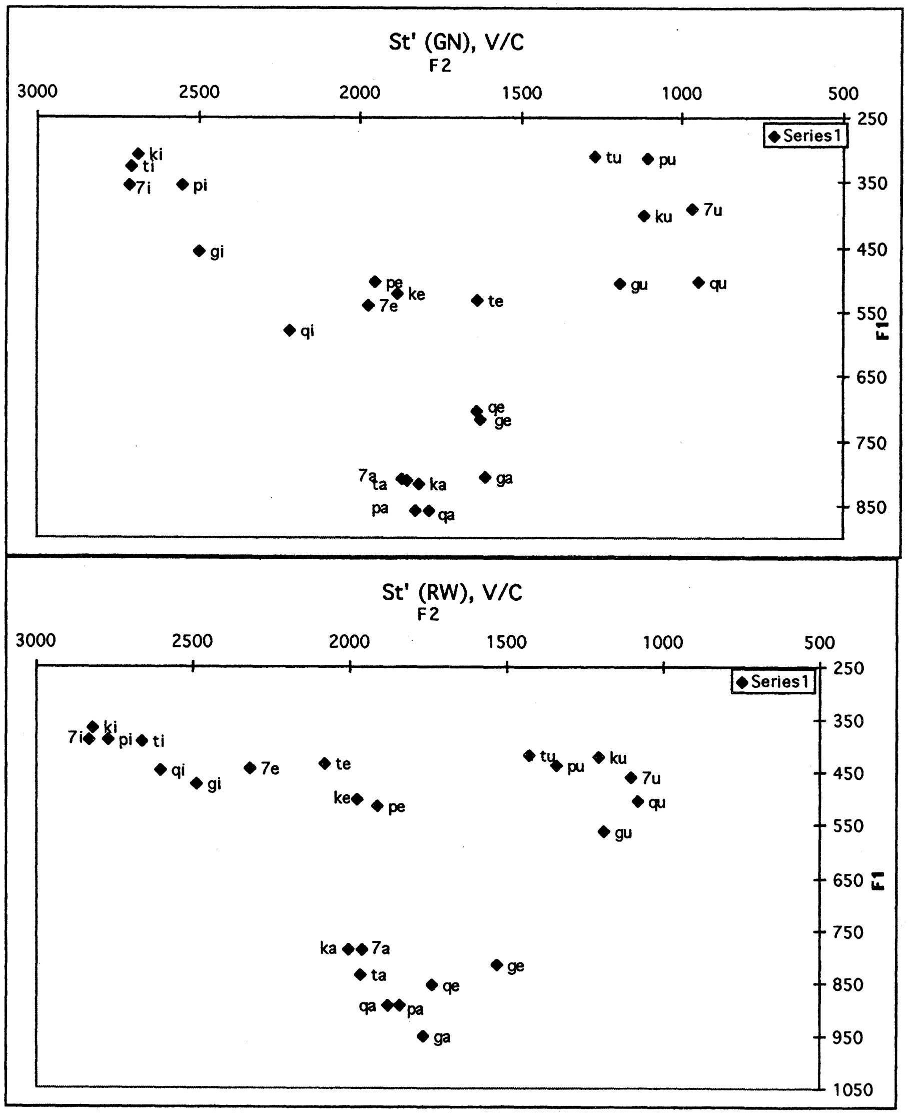
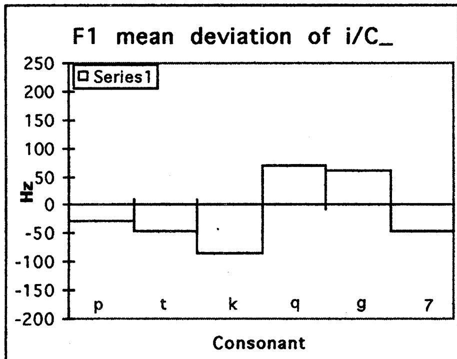


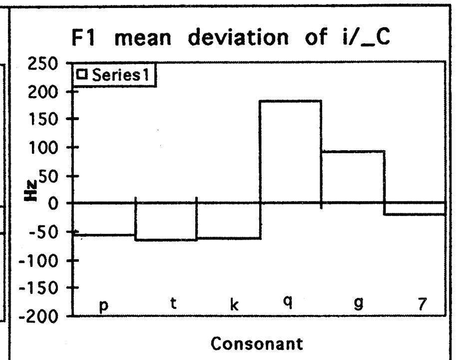
Figure 3: Consonantal effects on /i, a,u,e/.

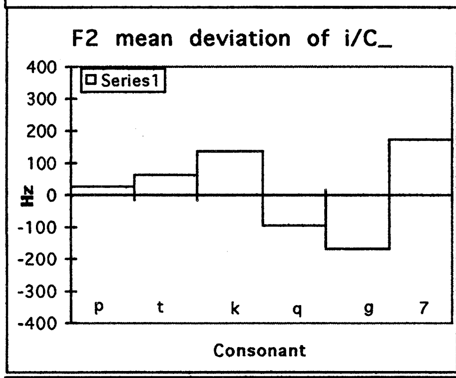
Again, the data show /q, g/ lowering and backing each vowel. This is true for all speakers. However, while /i, u, e/ have their most retracted values (lowered and backed) exclusively in the context of /q, g/, /a/ shows more variation. With /a/, consonantal context is less systematically influential: /q, g/ do not necessarily condition the most retracted allophones of a speaker's /a/ vowel. The split between /p, t, k, 7/ and /q,g/ is not consistent or extreme. /e/ shows the most extreme distinction between /q,g/ and /p, t, k, 7/, particularly in terms of F1 values. The value of schwa in the context of /p, t, k, 7/ ranges from mid-central [ə] to high-central [ɨ], with some fronted values. particularly in the context of /7/. This latter trend is undoubtedly because the two words used to elicit /7e/ sequences have a coronal after the vowel.

3.3 Positional effects on vowels: CV vs VC magnitude effects.

Recall that Set 1 varies the prevocalic consonant whereas Set 2 varies the postvocalic consonant. These sets are designed to investigate directional effects of consonants on vowels: does a post-vocalic consonant have more or less effect on a vowel than a prevocalic consonant? For each speaker, average F1 and F2 nucleus readings for each vowel in all consonantal contexts, both CV- and -VC sets, were calculated. This was then subtracted from the mean for that same speaker's vowel in a given consonantal context, first for the CV- and then for the -VC condition (see Maddieson and Wright (1995) for another example of this procedure). For example, for BN the average F1 and F2 values for all of his productions of /i/ are 362 Hz (F1) and 2200 Hz (F2). This was then subtracted from the mean of BN's /i/ vowels in the context of a preceding /p/, 327 Hz (F1) and 2218 Hz (F2). The result, -35 Hz for F1 and 18 Hz for F2, is a measure of deviation from the mean value of /i/ caused by a prevocalic /p/. The results from all speakers were then averaged, giving a measure of deviation across the speaker population. The averaged readings for F1 and F2 of each vowel are plotted in bar graphs, Figure 4, divided according to whether the consonant precedes or follows the vowel.


F1 mean deviation of i/C_
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant


F1 mean deviation of i/_C
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant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Series1
Hz
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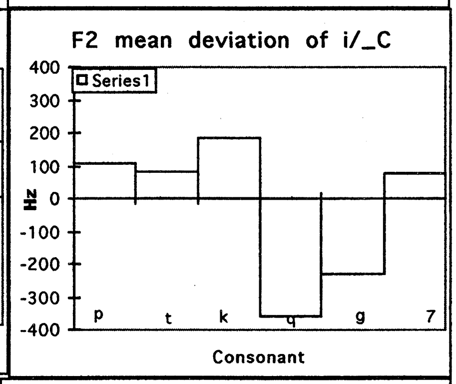
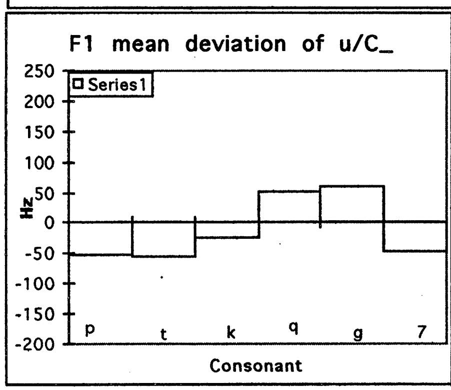
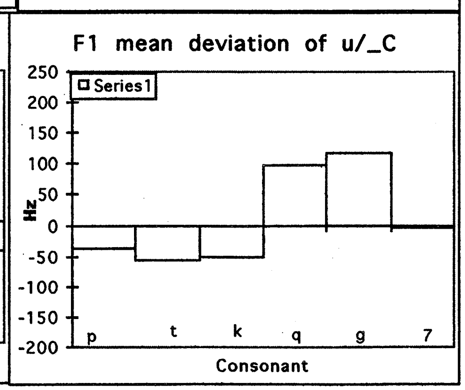
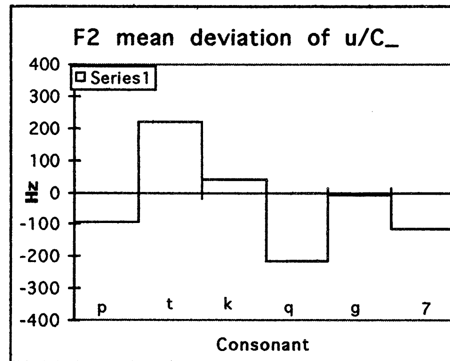
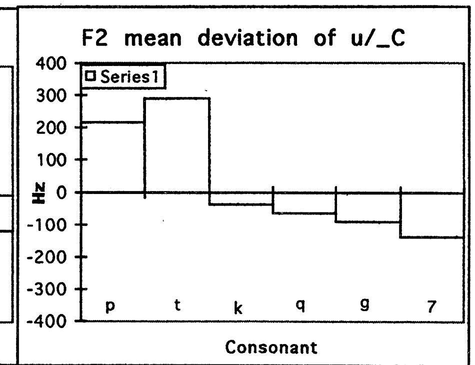
p t k q g 7
Consonant

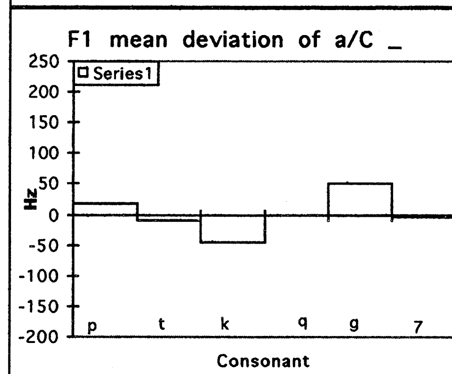

F2 mean deviation of i/_C
Series1
Hz
400 300 200 100 0 -100 -200 -300 -400
p t k q g 7
Consonant

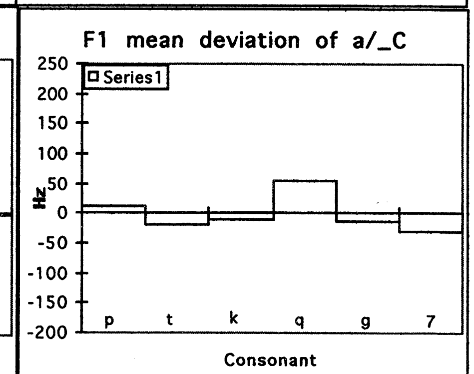

F1 mean deviation of u/C_
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant

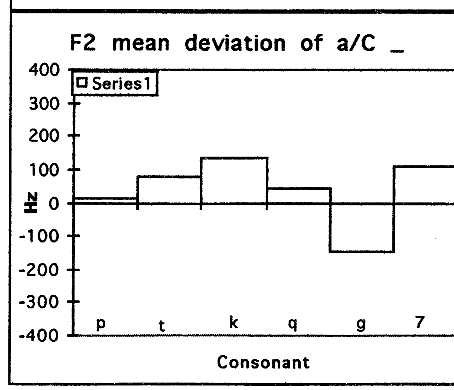

F1 mean deviation of u/_C
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant

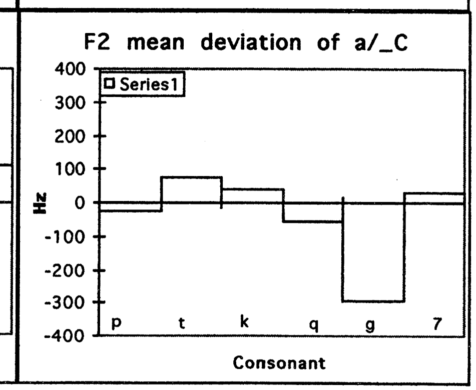

F2 mean deviation of u/C_
Series1
Hz
400 300 200 100 0 -100 -200 -300 -400
p t k q g 7
Consonant


F2 mean deviation of u/_C
Series1
Hz
400 300 200 100 0 -100 -200 -300 -400
p t k q g 7
Consonant


F1 mean deviation of a/C _
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant


F1 mean deviation of a/_C
Series1
Hz
250 200 150 100 50 0 -50 -100 -150 -200
p t k q g 7
Consonant


F2 mean deviation of a/C _
Series1
Hz
400 300 200 100 0 -100 -200 -300 -400
p t k q g 7
Consonant


F2 mean deviation of a/_C
Series1
Hz
400 300 200 100 0 -100 -200 -300 -400
p t k q g 7
Consonant

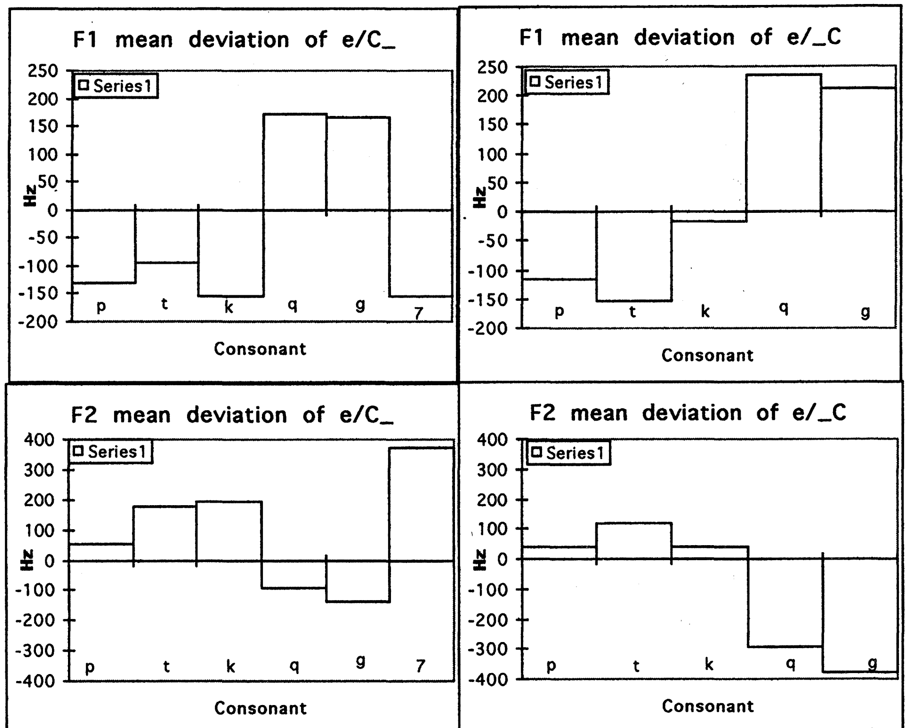


Figure 4: Deviation conditioned by consonantal context

The most consistent trend occurs with /q,g/. There is more F1 raising and F2 lowering (retracting) when /q, g/ follow a vowel than when they precede it. This trend is very clear for /i, e/ where only /q, g/ show any F1 raising and F2 lowering and the bar graphs for F1 show /i,e/ with more positive deviation from the norm (hence F1 raising) before /q, g/, and more negative deviation from the norm for F2 (hence F2 lowering). /u/ shows more F1 raising before /q, g/ and more F2 lowering before /g/ but not before /q/. /u/ is already a back vowel and variation in F2 values are fairly random, so this distribution is not too surprising. The /a/ vowel shows more F2 lowering before /q, g/, but more F1 raising before /q/ only. Again, /a/ is already a low vowel with relatively high F1 values and the variation in F1 movement across the data sets appears to be fairly random.

/p,t,k,7/ do not necessarily condition a consistent difference in vowel quality according to whether they precede or follow a vowel. For example, /t/ conditions more fronting (F2 raising) when it follows /i, u/ but not when it follows /e, a/.

4.0 Consonants

This section considers the phonetic profile of place in St' consonant production, using locus equations as developed by Lindblom (1963), Krull (1988) and Sussman et al. (1991). For our purposes, the particular value of this metric is that it provides a measure of vowel-induced coarticulation on consonants which complements the consonant-induced vowel variation examined in section 3.

Locus equations examine the relationship between F2 onset (or offset) and F2 nucleus for a consonant as it occurs in all vocalic contexts. For each vowel that occurs with a given consonant, F2 onset is plotted on the *y*-axis and F2 nucleus is plotted on the *x*-axis. The relationship between the two acoustic moments, across all vowels, is examined using a linear regression line fit to the cluster of (F2 nucleus, F2 onset) points. As an example, Figure 5 plots the locus equation for /pV/ data from speaker BN.

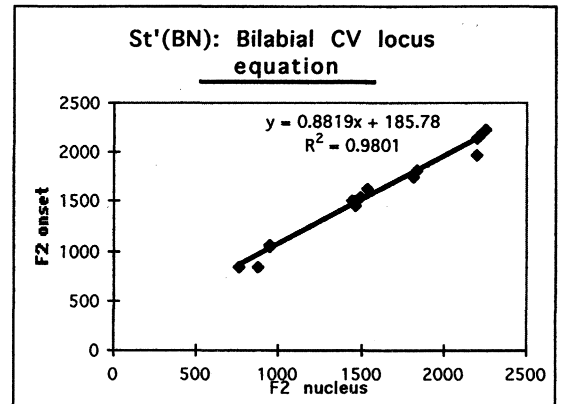


Figure 5: Locus equation

The slope of the regression line (.8819 in the example above) provides an index of vowel-induced coarticulation. A slope of 1 indicates complete coarticulation between consonant and vowel (F2 nucleus must equal F2 onset for a slope of 1). Slopes of less than 1 indicate less coarticulation between consonant and vowel. Locus equation studies have shown that the y-intercept (where the regression line intersects with the y-axis, +185.78 in the example) together with slope, uniquely characterize consonantal place of articulation. R2 is a measure of how much variance in F2 onset (the dependent variable) can be accounted for by F2 nucleus (the independent variable). A high R2 indicates a close relation between the two variables. Results for all speakers are given in Table 2.

Table 2: Consonant locus equations: CV and VC .

	Slope	y-intercept	R2	Slope	y-intercept	R2
	pV			Vp		
BN	0.882	185.78	0.980	1.034	-400.8	0.895
GN	0.961	-22.675	0.955	0.765	-12.934	0.831
RW	0.876	100.69	0.94	0.357	872.67	0.421
BF	0.847	121.92	0.938	0.701	136.72	0.888
Avg	0.891	96.429	0.953	0.716	148.914	0.759
sd	0.049	87.250	0.0120	0.281	533.026	0.227
	tV			Vt		
bned	0.590	812.91	0.866	0.788	460.95	0.805
gned	0.608	947.19	0.939	0.586	960.84	0.777
rwhit	0.607	955.27	0.897	0.807	441.19	0.906
bfrank	0.734	695.49	0.889	0.917	226.67	0.956
Avg	0.635	852.715	0.897	0.774	522.412	0.861
sd	0.067	123.487	0.030	0.138	310.943	0.084
	kV			Vk		
bned	0.931	237.98	0.877	1.153	-199.91	0.964
gned	0.994	110.52	0.931	1.135	217.19	0.948
rwhit	0.994	110.52	0.931	1.102	-191.55	0.98
bfrank	1.016	14.029	0.942	1.111	-260.48	0.982
Avg	0.984	118.262	0.920	1.125	-108.688	0.968
sd	0.037	91.864	0.029	0.023	219.412	0.016
	qV			Vq		
bned	0.746	315.75	0.930	0.85	11.474	0.872
gned	0.806	222.6	0.954	1.007	198.04	0.921
rwhit	0.637	363.61	0.906	0.879	-74.725	0.927
bfrank	0.685	370.64	0.909	0.774	108.66	0.880
Avg	0.718	318.15	0.925	0.877	60.862	0.9
sd	0.073	68.209	0.022	0.097	118.22	0.028
	gV			VG		
bned	0.535	402.37	0.6624	0.69	296.6	0.8366
gned	0.565	432.86	0.5795	0.867	71.035	0.8112
rwhit	0.472	470.88	0.6402	0.724	177.14	0.7087
bfrank	0.602	346.96	0.8579	0.632	424.09	0.7561
Avg	0.543	413.267	0.685	0.728	242.216	0.778
sd	0.055	52.340	0.120	1.00	152.287	0.057
	7V			V7		
bned	0.995	21.128	0.977	1.1	-102.01	0.989
gned	0.90	95.408	0.967	1.108	-187.79	0.989
rwhit	1.108	-51.744	0.981	0.998	-23.041	0.986
bfrank	0.97	42.177	0.923	1.022	-83.942	0.997
Avg	0.993	26.742	0.962	1.057	-99.196	0.990
sd	0.087	60.950	0.026	0.055	-68.04	0.005
Grand Average	0.794	304.26	.89	0.88	127.75	0.876

In the Salish data, the average slope of VC, across consonants, is higher than CV (.88 compared to .79). Slopes in individual VC sequences are higher for each of /t, k, q, g, 7/. The difference is marginal for /7/ and /k/, however. Thus, it is /t, q, g/ which show clear evidence for more coarticulation in VC position than CV position. Average R2 values for the two positions are very close: .89 for CV and .876 for VC. Individual R2 values for VC and CV are likewise relatively close except for /p, g/, which show reverse trends (a higher R2 for pV, a lower R2 for gV). On this measure then, there appears to be little systematic difference between the two contexts. In terms of location in consonantal space as defined by slope and y-intercept, consonants are slightly less dispersed inVC space, see Figure (6).

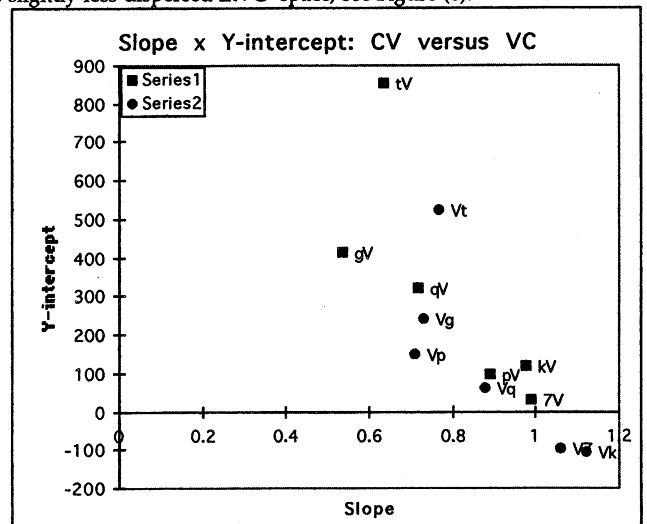


Figure 6: Locus equation space

Previous studies of locus equations in CV and VC conditions show that consonantal place of articulation is less reliably encoded in post-vocalic position,[1] at least for English /b, d, g/ (Sussman et al. 1997). Sussman's study found that in VC context, slope was lower overall (except for /d/ where it was constant), R2 was lower, and consonants were less dispersed in the space defined by slope and y-intercept. Salish, then, does not entirely match the profile for English. Instead, VC position shows greater coarticulation (measured as degree of slope) for three of the six consonantal positions examined (/t, q, g/). Admittedly, none of /q, g, 7/ were measured in Sussman's study of English, so data cannot be compared for these consonants. However, both R2 and consonant dispersion are less affected by position in Salish, compared to English. Salish R2 values do not radically differentiate CV from VC, either overall or within each place, except for /p, g/. Consonants inVC space are reasonably well separated and dispersed compared with CV space.

[1]Note that locus equations are calculated solely on the basis of information present in the vowel. Information present in the burst release of consonants is not referred to.

5.0 Discussion

To summarize, the results from section 3 indicate that /q, g/ in particular have a greater effect on the nucleus value of preceding vowels than following vowels. Thus, for these segments, the vowel anticipates the following consonant and carries a considerable amount of consonantal place information. The same bias does not seem to hold for the remaining consonants, /p, t, k, 7/, where there is considerable random variation in the CV and VC profiles. Slope information from locus equations (section 4) indicates that Vt, Vq and Vg structures in St' are overall more heavily coarticulated than their CV counterparts. R2 and (slope,y-intercept) space do not clearly differentiate between the two contexts. Since there are only four speakers statistical comparison of results was not undertaken.

We turn first to the facts about vowel coarticulation with a consonant (section3). An obvious question is why /q, g/ provoke such extensive anticipatory coarticulation on vowels, while oral consonants and /7/ do not. A related, but more basic question is whether the Salish data reflect a language-specific (that is to say, linguisitic) organization, or whether more general articulatory mechanics are at play. If anticipatory coarticulation of V with C is a side-effect of vocal mechanics, then the muscle masses and gestures uniquely involved in uvular and pharyngeal articulation must somehow dictate the distinction observed here. Without adequate models of uvular/pharyngeal articulation it is difficult to further this hypothesis, except by examining CV and VC sequences in other languages with /q, ʕ/, such as Arabic or some of the Caucasian languages. If similar local coarticulatory patterns are found there, then general articulatory mechanics may be at play. If differences are found, we must examine inventory and/or prosodic structure.

Locus equations show post-vocalic /t, q, g/ with greater slope, hence greater coarticulation of C with V. We also know that /q, g/ condition greater anticipatory movement on a preceding vowel, hence greater coarticulation of V with C. Thus, /Vq/ and /Vg/ units are coarticulated in both directions: overall C place is affected by V (locus equation slope) and V is affected by C (formant values at the nucleus). The /t/ locus equation slope shows more vocalic effects on final /t/ than initial /t/, but we do not have consistent evidence for more fronted vowels with a following /t/ (overall /it, ut/ are more fronted, /et, at/ are not). This underlines the uniqueness of /q, g/ compared to other places of articulation in St'.

Finally, the findings have some bearing on Interior Salish phonology. Interior Salish retraction, both local and long-distance, has received considerable attention (Cole 1987, Czaykowska-Higgins 1990, Doak 1987, 1989, 1992, Bessell 1992, among others). The regressive retraction harmony found in Coeur d'Alene and the Spokane-Kalispel-Flathead continuum is particularly unusual in that a consonant (a uvular or a pharyngeal) induces a long-distance effect on a vowel.[2] Usually, adjacency is required for consonant-vowel interaction, and certainly most of the consonant-vowel interactions in Interior Salish respect adjacency. However, the data presented here verify a phonetic basis for the directional bias of the long-distance harmony, and the restriction of harmony to segments with uvular/pharyngeal articulation: other segments simply do not exhibit the same asymmetry between anticipatory and perseverative consonant-vowel interaction.

[2] In some cases other consonants also induce regressive harmony, for instance, the /r, r'/ of Coeur d'Alene, which is assumed to have some kind of pharyngeal constriction in common with uvulars and pharyngeals proper.

Appendix A: St'át'imcets elicitation

The database is designed to elicit vowel-consonant and consonant-vowel combinations , where the consonant is a stop that varies by place of articulation only, except in the case of 'g', which is a pharyngeal glide.

Symbol conversion to IPA

r=ɣ	c=x	ts=tʃ	e=ə	7=ʔ
t'=tɬ'	lh=ɬ	x=χ	g=ʕ	

Set 1: CV

Ci

cwelpílc	to turn around
cwpilc	to sit up from lying position
tɬ7texw	right, correct
ptínusem	to think
kítsets	to get laid up
kítsin'	to put things down
qícten	elbow
tqílh t'u7	almost
gítsmen	teeth
gíslc	shrink
lh7ílc	to get close to sth
cw7ít	lots, plenty

Ca

papt	always
spálem	prairie, field
tákem	all
tálhlec	to stand up fr. sitting
kalh	us
skas	how?
qam't	to get hit
sqátsza7	father
gap	evening
7áma	good
7alkst	to work

Set 2: VC

iC

lhípsem	to blink one's eyes
rípcal	to raise, make grow
sítkem	to make a net
tsitcw	house
síkil	tree bark
cíkin'	to push sb, sth
t'iq	to arrive (here)
tsíqen	to stab
p'egp'íg'lha	frog
igítsmen	his teeth
ts'i7	deer, meat
kí7kel'	lazy

aC

splap	buttocks
sápen	daughter in law
swat	who?
pátsa7	digging stick
ptak	to pass by
n7aláka7	shoulder
t'áqsa7	BBQ'd salmon
(s)met'áqa7	mushroom
págpgem	faded, grey
se7ágcen	crow
sta7	aunt
ca7	high

Cu	
pus	wet
put	sufficient, just right
túpusn	punch sb in face
tsulhn'	point to sth
zelkú7	choke cherries
kútqsan'	to pout
qul	full (with liquid)
qu7	water
gúy't	to sleep
gútsets	have a miscarriage
7ú7sa7	egg
7usts	to throw out

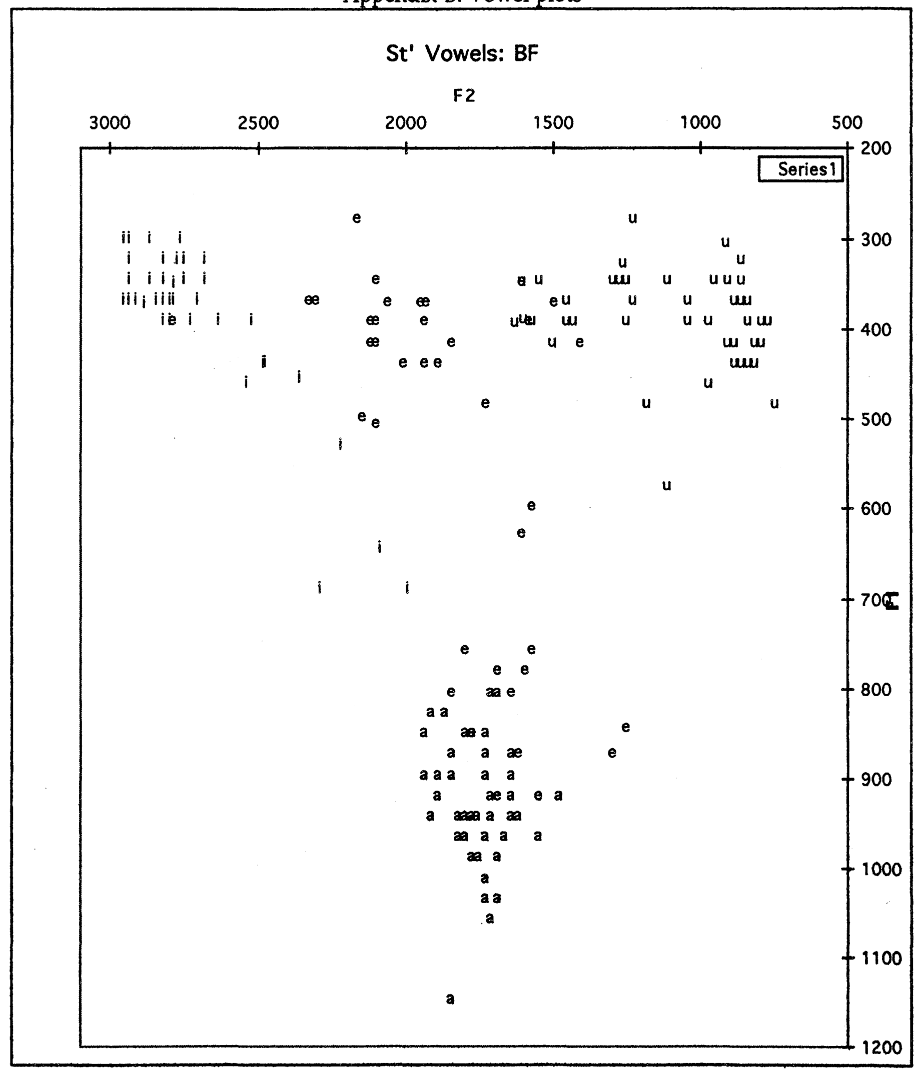
Ce	
pél'p	to be lost
péten	cover sth
stemtétem'	clothes, belongings
tékpen	to sting
skésen	messenger
képen	to touch lightly
qemp	hot
qélhen	bury, store away
gétsen	to tie it
gélgel	strong
s7ents	I
7éts7a	towards here

uC	
súpaya	itchiness, excema
túpusen	to punch sb in face
sútik	winter
tsut	to say sth
tsukw	enough, finished
nkúkwtsa	downstream area
7úqwa7	to drink
tsúqwun'	lengthen, add sth (splice a rope)
tsúgwla7	steelhead
stsúgwtsugw	stripes
zelkú7	choke cherries
7ú7sa7	egg

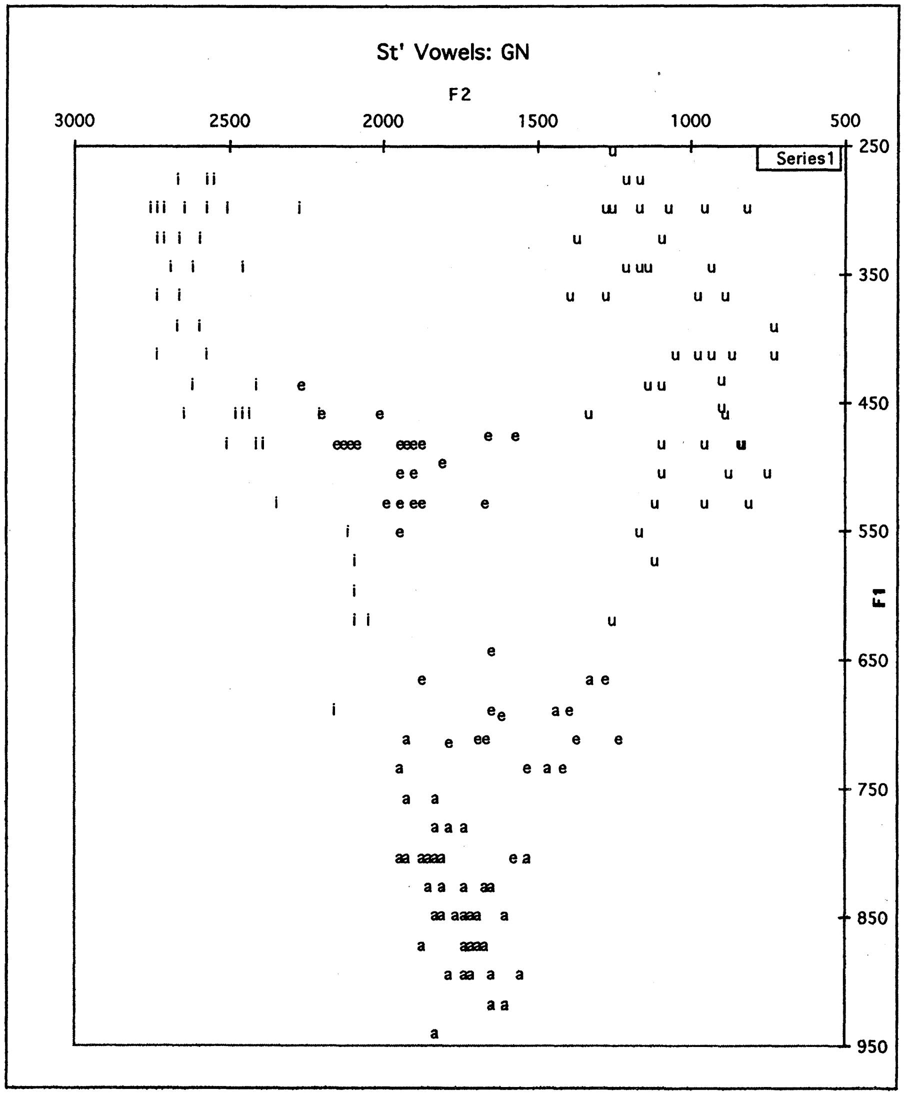
eC	
képen	to touch lightly
kactépa	to faint, pass out
métsen	to write it down
k'éten	to poke, stab,pierce
xéken	to count it
sékmen	whip, stick
peq	white
téqen	to touch sth
tségen	to rip, tear it
lhéggep	to get sold

NOT AVAILABLE: e7 sequences do not occur

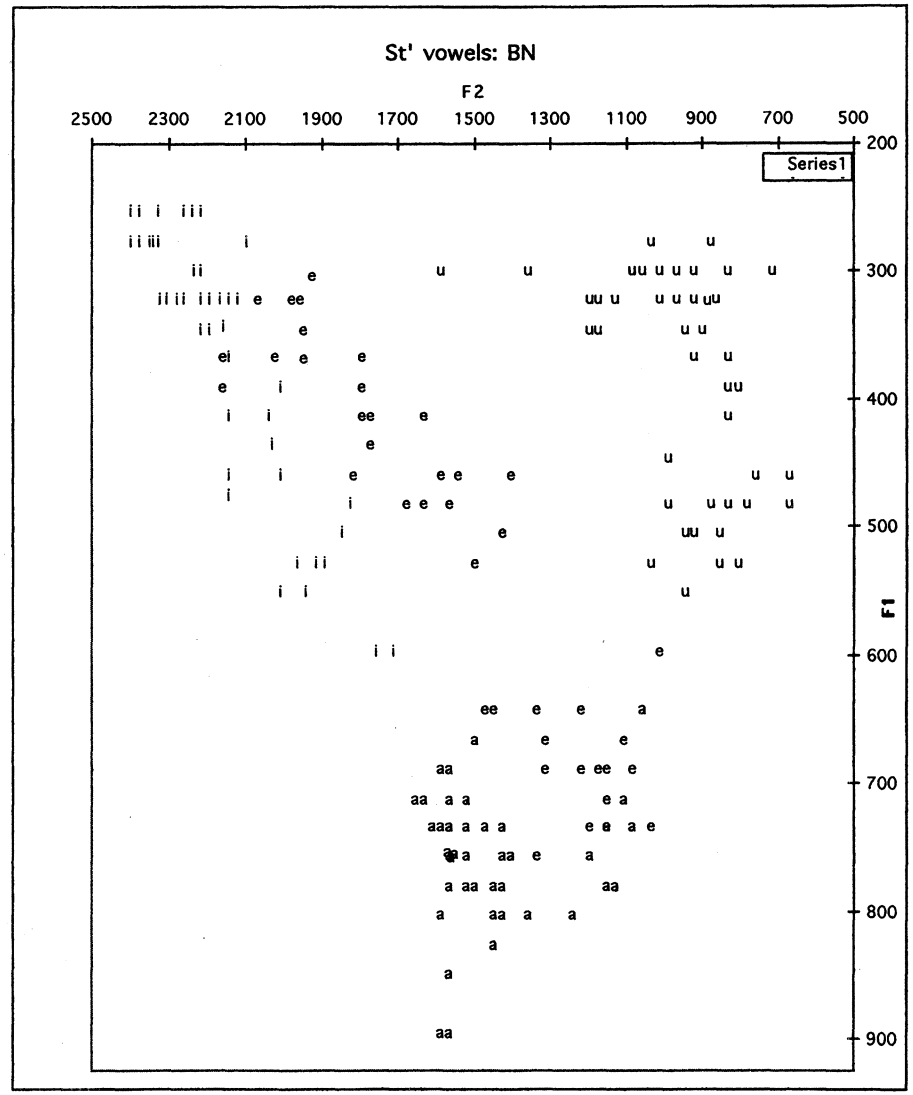
Appendix B: Vowel plots

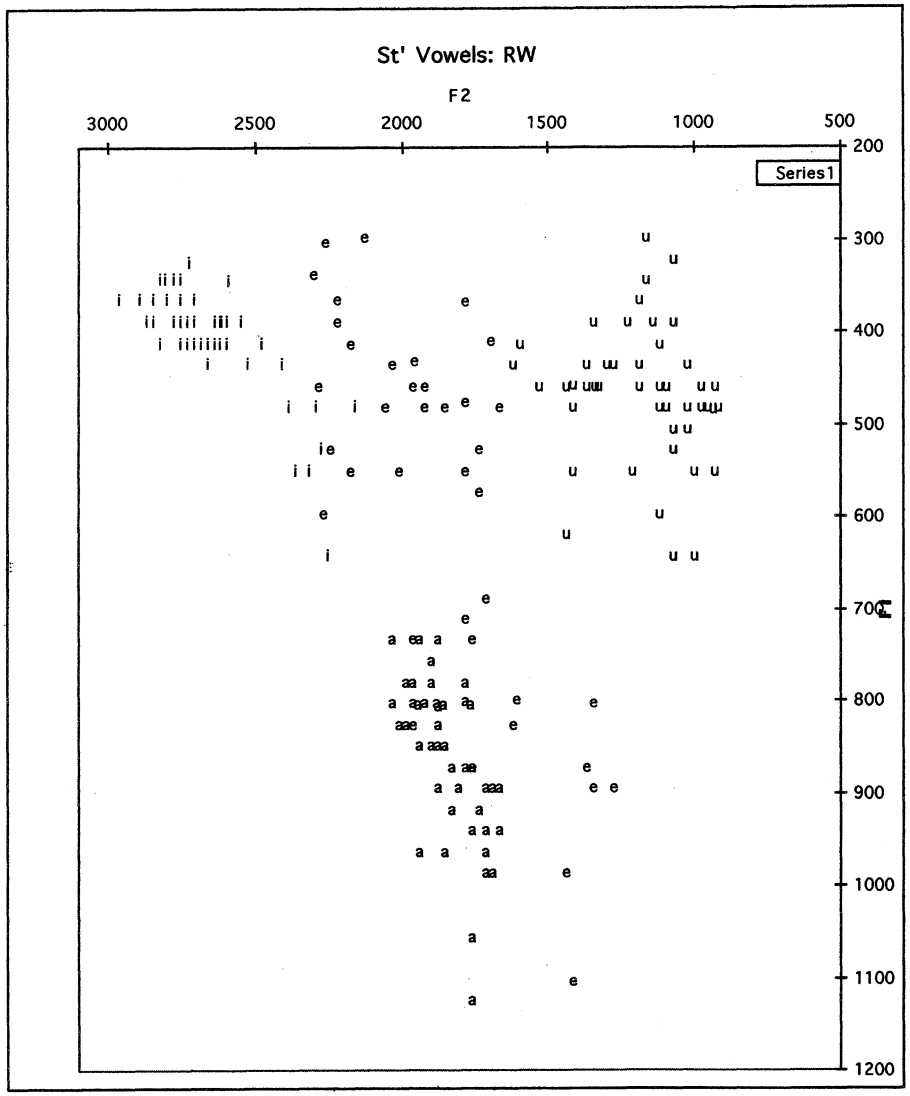


82


St' Vowels: GN
F2
3000
2500
2000
1500
1000
500
250
350
450
550
650
750
850
950
F1
Series1

83


St' vowels: BN
F2
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
200
300
400
500
600
700
800
900
F1
Series1



References

Bessell, N. 1992. Towards a phonetic and phonological typology of post-velar articulation. PhD dissertation, UBC.

Cole, J. 1987. Planar phonology and morphology. PhD dissertation, MIT.

Czaykowska-Higgins, E. 1990. Retraction in Moses-Columbia Salish. ICSNL 25.

Doak, I. 1987. Coeur d'Alene vowel harmony. ICSNL 22.

Doak, I. 1989. A non-linear solution to Proto-Salish retraction. ICSNL 24.

Doak, I. 1992. Another look at Coeur d'Alene vowel harmony. IJAL 58:1-35.

Krull, D. 1988. Acoustic properties as predictors of perceptaul responses. A study of Swedish voiced stops. Phonetic Experimental Research at the Institute of Linguistics, University of Stockholm, VII: 66-70.

Lindblom, B. 1963. On vowel reduction. The Royal Institute of Technology Speech Transmission Laboratory Report 29.

Maddieson, I. and R. Wright. 1995. The vowels and consonants of Amis—a preliminary phonetic report. UCLAWPP 91:45-66.

Sussman, H.M., Bessell, N., Dalston, E., and Majors, T. 1997. An investigation of stop place of articulation as a function of syllable position: a locus equation perspective. Journal of the Acoustical Society of America 101: 2826-2838.

Sussman, H. M., McCaffrey, H. A., and Mathews, S. A. 1991. An investigation of locus equations as a source of relational invariance for stop place categorization. Journal of the Acoustical Society of America 90: 1309-1325.

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