Universality of Articulatory Conflict Resolution: Evidence from Salish Languages*

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Previous research has shown that in cases where two adjacent target sounds create an articulatory conflict, speakers tend either to insert an epenthetic element between the two (fully achieved) sounds or to compromise the articulation of one of the sounds. In this paper we focus on the pronunciation of /qi/ and /iq/ sequences in SENĆOŦEN. We show that /qi/ sequences are pronounced with a retracted vowel ([qɪ]) whereas /iq/ sequences are pronounced with a transitional fricative [i^{x}q]. These results are compared to the patterns described in other Salish languages, and discussed in terms of their implications for phonetic typology.

Key words: Saanich, Northern Straits Salish, speech production, co-articulation, articulatory conflict, Salish languages

1. Introduction.

This paper explores articulatory conflicts, and how they are resolved across languages. More specifically, we consider sequences /qi/ and /iq/ in Salish languages. Based on how these sequences are pronounced across a variety of Salish languages, we address two questions raised by Gick & Wilson's (2006) typology of conflict resolution strategies, adding to the growing body of literature on the phonetics of Salish languages.

The paper is laid out as follows: we begin with a description of articulatory conflicts and of the strategies which have been proposed by Gick & Wilson (2006) to resolve them, outlining two questions raised by their work (section 2). We then report on an experiment on SENĆOŦEN[1] designed to address these questions (section 3). We compare the SENĆOŦEN results with those reported in previous studies of Salish languages and discuss the implications of the Salish facts as a whole for Gick & Wilson's proposals (section 4.1). We conclude with a discussion of the value of auditory vs. acoustic analysis in understanding sound pronunciation (section 4.2).

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[1] Pronounced [sə'ntʃɑθən] and known as Saanich in the linguistic and anthropological literature, it is a dialect of Northern Straits Salish. See Appendix for the conversion between the Elliott alphabet, the International Phonetic Alphabet (IPA) and the American Phonetic Alphabet (APA).

1.1 Background.

Articulatory conflicts arise when two adjacent sounds – or targets (Browman & Goldstein 1992) – impose conflicting requirements on a particular articulator. Take for example the sequence /qi/, in which the tongue must be retracted for /q/ but advanced for /i/[2]. The tongue cannot move instantaneously between retracted and advanced positions, and as a result an articulatory conflict arises. Gick & Wilson (2006) propose three strategies for resolving such conflicts: a) a transitional element can be inserted between the two fully achieved targets, b) one of the targets can be compromised, or c) one of the targets can be deleted entirely.

In their discussion, Gick & Wilson adopt an Optimality Theoretic approach (McCarthy & Prince 1993; Prince & Smolensky 1993) to Articulatory Phonology (Browman & Goldstein 1992). Considering only strategies a) and b) above, and using three constraints outlined in Gafos (2002), they propose a factorial typology of four language types, each of which uses a different combination of strategies to resolve the articulatory conflicts created by the sequences /qi/ and /iq/. The first constraint, IDENT(TARGET)[3] requires that the surface representation of each target remain faithful to its underlying representation. This constraint prevents compromising either target to resolve the articulatory conflict. The second and third constraints, CV-COORD and VC-COORD, prevent the articulators responsible for achieving CV and VC sequences to be mis-coordinated (or mis-timed). These constraints therefore mitigate against an epenthetic segment being inserting between targets. The factorial typology resulting from ranking these three constraints in all possible ways is presented in (1).

(1) Factorial typology of languages as outlined in Gick & Wilson (2006)

	Ranking	*Strategy*	*Example language*
A.	IDENT(TARGET) >> CV-COORD, VC-COORD	/qi/ → q^{ə}i /iq/ → i^{ə}q	Not yet attested
B.	CV-COORD, VC-COORD >> IDENT(TARGET)	/qi/ → qɪ /iq/ → ɪq	Skye Scots Gaelic
C.	CV-COORD >> IDENT(TARGET) >> VC-COORD	/qi/ → qɪ /iq/ → i^{ə}q	Nuu-chah-nulth
D.	VC-COORD >> IDENT(TARGET) >> CV-COORD	/qi/ → q^{ə}i /iq/ → ɪq	Tsilhqut'in[4]

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[2] Throughout the paper, we use "retraction" in a general way, not distinguishing between tongue raising (uvularization) and backing (pharyngealization). Future articulatory studies will allow us to determine exactly what the nature of retraction is in SENĆOŦEN.

[3] Constraint names are from Gick & Wilson (2006).

[4] Tsilhqut'in is included here, as it is reported in Gick & Wilson (2006) and based on Cook (1993). However, recent discussion with a fluent Tsilhqut'in speaker leads us to believe this analysis may not be quite right. Future research will hopefully clarify the Tsilhqut'in facts.

In language type A, IDENT(TARGET) is ranked highest, ensuring that both /q/ and /i/ targets are fully achieved, at the expense of CV-COORD and VC-COORD. This leads to symmetrical conflict resolution, with epenthetic segments inserted between targets in both /qi/ and /iq/ sequences

In language type B, IDENT(TARGET) is ranked lowest. This also results in symmetrical conflict resolution, but in this case a target is compromised in both /qi/ and /iq/ sequences in order to satisfy CV-COORD and VC-COORD. Note that in their examples, Gick & Wilson assume that it is the vowel that is affected in cases of compromise (e.g. /qi/ → [qɪ]). Another possibility is that the consonant is affected (e.g. /qi/ → [ki]). It seems likely that the compromised target is chosen so as to minimize loss of contrast in the language: in languages without a [q ~ k] contrast, one would expect the consonant to be compromised; in languages with a single high front vowel, one would expect the vowel to be compromised. In either case, the compromise will minimize loss of contrast in the language because it will not lead to the neutralization of two phonemes. This issue is discussed further in section 4.

In language type C, IDENT(TARGET) is ranked between the CV-COORD and VC-COORD. The result is asymmetrical conflict resolution: ranking CV-COORD above IDENT(TARGET) means that in /qi/ sequences (CV), compromising a target incurs a less serious violation than inserting an epenthetic segment, leading to [qɪ]. Ranking IDENT(TARGET) above VC-COORD means that in /iq/ sequences (VC), the opposite pattern holds: inserting an epenthetic segment incurs a less serious violation than compromising a target, leading to [iᵊq]. Language type D is similar to C, also exhibiting asymmetrical conflict resolution, but the opposite ranking of CV-COORD and VC-COORD leads to opposite strategies being used: /qi/ surfaces as [qᵊi] and /iq/ surfaces as [ɪq].

Two related questions are raised by the factorial typology outlined in (1) above: 1) are all languages in the typology actually attested, and 2) are they attested with equal frequency? If the answer to either of these questions is 'no', then an explanation must be given as to why not – more specifically, is it because of universal articulatory or perceptual restrictions? If so, which ones? In answer to the first question, Gick & Wilson report that no language of type A (qᵊi; iᵊq) has yet been attested. It is possible however that further typological work will uncover languages that do exhibit this pattern. In answer to the second question, Gick & Wilson suggest that articulatory conflict resolution strategies tend to be asymmetrical, possibly for perceptual reasons (see section 4.2 for details). Thus, language types C and D should be more common than language types A and B. To determine whether or not this is actually the case, data from a wide variety of languages must be considered.

As a step further towards answering the two questions above, an experiment was designed to determine how /qi/ and /iq/ sequences are pronounced in SENĆOŦEN, a dialect of North Straits Salish (of the Central Salish family), traditionally spoken on the

Saanich peninsula of Vancouver Island and on the neighbouring Gulf and San Jan islands. SENĆOŦEN is highly endangered, with fewer than thirty fluent speakers remaining, all over sixty years of age. Like other Salish languages, SENĆOŦEN has an extremely rich consonantal inventory, including the uvular stop /q/, as well as the high front vowel /i/[5]. Consonant and vowel inventories are provided in Figures 1 and 2.

p		t		tʃ	(k)	kʷ	q	qʷ	
p’	tθ’	t’	tɬ’	tʃ’		k’ʷ	q’	q’ʷ	ʔ
	θ	s	ɬ	ʃ		xʷ	χ	χʷ	h
m		n	l	j		w	ɴ		
m’		n’	l’	j’		w’	ɴ’		

Figure 1. SENĆOŦEN consonant inventory (adapted from Montler, 1986:7).

i	ə	(u)
	e	a

Figure 2. SENĆOŦEN vowel inventory (adapted from Montler, 1986:7).

In addition to conducting experimental research on SENĆOŦEN, a review of the literature on Salish languages was conducted, to gain a fuller picture of how these languages as a whole pattern with respect to the pronunciation of /qi/ and /iq/ sequences. As we shall see, Salish languages seem to fall into two distinct sets with respect to pronunciation, corresponding to language sub-family as well as geographical location.

2. Experiment.

2.1 Methodology and procedure.

For this study we analyzed SENĆOŦEN words containing /qi/ and /iq/ sequences. The words were chosen from Montler (1991) and from a draft dictionary compiled by SENĆOŦEN speakers. Each word was checked and recorded by two fluent SENĆOŦEN speakers. Speaker 1, a big house speaker, is from the West Saanich reserve known as Tsartlip. Speaker 2 is from the East Saanich reserve known as Tsawout. The words were

[5] See section 4.2 for a discussion of the phonetic details of this vowel.

recorded in isolation on a digital M-Audio MicroTrack recorder and a Sony EMC-MS908C microphone, uploaded to a PC computer running Windows using Audacity (Sourceforge.net 2006) and analyzed using PRAAT (Boersma & Weenink 2006). For each word, the recording proceeded in three steps: Speaker 1 provided three repetitions of the SENĆOTEN word; one of the experimenters then provided the English translation; following the translation Speaker 2 provided three additional repetitions of the SENĆOȾEN word. Only the second repetition for each speaker was analyzed.

2.2 Tokens.

Three independent variables were considered in this study: speaker (Speaker 1 vs. Speaker 2), stress (stressed vs. unstressed /i/), and segmental position (/qi/ vs. /iq/)[6]. A fourth variable, context (words in isolation vs. embedded in sentences), was initially included as well, but due to elicitation difficulties[7], the results of the study are based only on isolated words. The dependant variable in this study was the co-articulation strategy used (details are provided below).

Table 1 provides example tokens elicited for this study. Each token is written in the International Phonetic Alphabet and the Dave Elliott Alphabet[8]. An English gloss is also provided.

	/qi/	/iq/
Stressed	s**qí**m'ək'ʷ S<u>K</u>IMEQ 'octopus, devil fish'	st'**íq**əl SDI<u>K</u>EL 'mud'
Unstressed	θə́**qi** ȾE<u>K</u>I 'sockeye salmon'	ʃəʃ**iq**ámə ŚEŚI<u>K</u>OME 'fine dry snow'

Table 1. Words illustrating the two stress and two segmental positions considered.

Table 2 summarizes the number of tokens per speaker elicited for this study. Note that the number of tokens varies by condition. In particular, many more tokens were

[6] All /qi/ sequences were syllabified as part of a single syllable, /q/ as the onset and /i/ as the nucleus. Of the /iq/ sequences, 11 consisted of two separate syllables: [i.qV] and 3 consisted of a single syllable: [iq.CV].

[7] It became clear after the first few sentences elicited that the speakers were not comfortable coming up with sentences spontaneously. We hope in the future to be able to elicit more spontaneous speech from the two speakers, including words embedded in sentential contexts.

[8] The Dave Elliott alphabet was created by a Saanich Elder Dave Elliott Sr. approximately 30 years ago. It is the preferred orthography of the two speakers with whom we worked, and is included here to make the paper more accessible to community members.

elicited in stressed than in unstressed position. This shortcoming is partly due to distributional facts of /qi/ and /iq/ in SENĆOŦEN: underlying /i/ reduces to schwa when unstressed, such that the only unstressed /i/ tokens derive from /y/ that has vocalized due to its position in the word (Montler 1986; Leonard 2007). In addition, there are simply few words with /qi/ and /iq/ sequences. In Montler's corpus of 13,000 utterances, there are only 82 occurrences of /iq/ and 102 of /qi/, found in a very small set of words[9]. This shortcoming is also partly due to methodological limitations. At this stage, experimenters only have access to a limited database of words and utterances. We are currently building on this database with the help of our language consultants. In order to include as many tokens as possible overall, it was necessary to accept uneven token counts across conditions. A single token (from Speaker 2, in the stressed /qi/ condition) was excluded from analysis due to mispronunciation. In total then, 73 tokens were analyzed: 37 for Speaker 1 and 36 for Speaker 2 (numbers in parentheses are for Speaker 2).

	/qi/	/iq/	Total
Stressed	18 (17)	11	29 (28)
Unstressed	5	3	8
Total	23 (22)	14	37 (36)

Table 2. Token numbers per speaker.

2.3. Analyzing the data.

The data were analyzed in two ways: auditorily and acoustically. The auditory analysis was based on the auditory impressions of two trained phoneticians (the authors), and supported by qualitative spectrogram analysis. From this analysis, it was determined that three main conflict resolution strategies were being used: a) vowel retraction (e.g. /qi/ → [qɪ]), b) a transitional vowel (e.g. /qi/ → [q^{ə}i]), and c) transitional frication (e.g. /qi/ → [q^{x}i]). In some cases, speakers used a combination of transitional frication and vowel retraction, or of transitional frication and transitional vowel. In addition, a small number of tokens appeared not to exhibit any conflict resolution strategy at all (see section 4.2 for discussion).

Figures 3 through 6 illustrate the different strategies observed. Figure 3 provides an example that was coded auditorily as 'vowel retraction'. The word represented in the spectrogram is [sqím'ək'^{w}]: 'octopus, devil fish' as pronounced by Speaker 2. The portion of the word that is highlighted represents the vowel /i/. What is important to note is that the formants are relatively stable indicating that there is no transitional element between the uvular stop and the vowel. Rather, the vowel is retracted over its entire duration, as reflected in its stable first and second formants: F1 measures 411 Hz at onset and 386 Hz at vowel midpoint and F2 measures 2087 Hz at its onset and 2099 Hz at its

[9] Timothy Montler, personal communication.

offset[10]. While these values do indicate some formant movement, the differences between onset and midpoint frequencies are much smaller than they are for the transitional vowels – as illustrated in Figure 4.

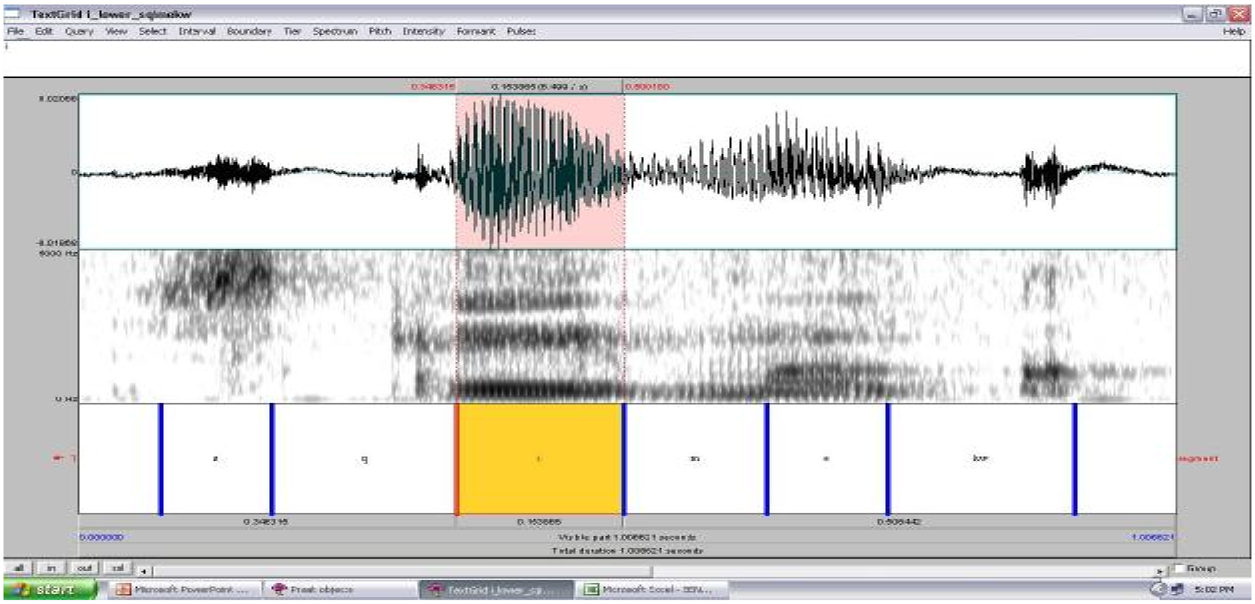

Figure 3. Vowel retraction in SKIMEQ – [sqím’ək’^{w}]: ‘octopus, devil fish’.

Figure 4 is an example that was coded as ‘transitional vowel’. The word represented in the spectrogram is [t’əm’íqən]: ‘get hit on the belly’ as pronounced by Speaker 2. The portion of the word that is highlighted represents the portion of the vowel /i/ which is transitioning into the uvular stop. The formants are not as stable as they are in Figure 3, indicating that there is a transitional element between the uvular stop and the vowel. In this case, F1 rises from 383 Hz at vowel midpoint to 473 Hz at vowel offset (adjacent to /q/), and F2 drops from 2022 Hz at vowel midpoint to 1897 Hz at vowel offset. These changes in frequency are more pronounced than are those observed in Figure 3.

[10] Note that retraction is reflected here primarily by lowered F1 values; F2 values remain relatively high throughout the data as a whole. This point is discussed in section 4.2 below.

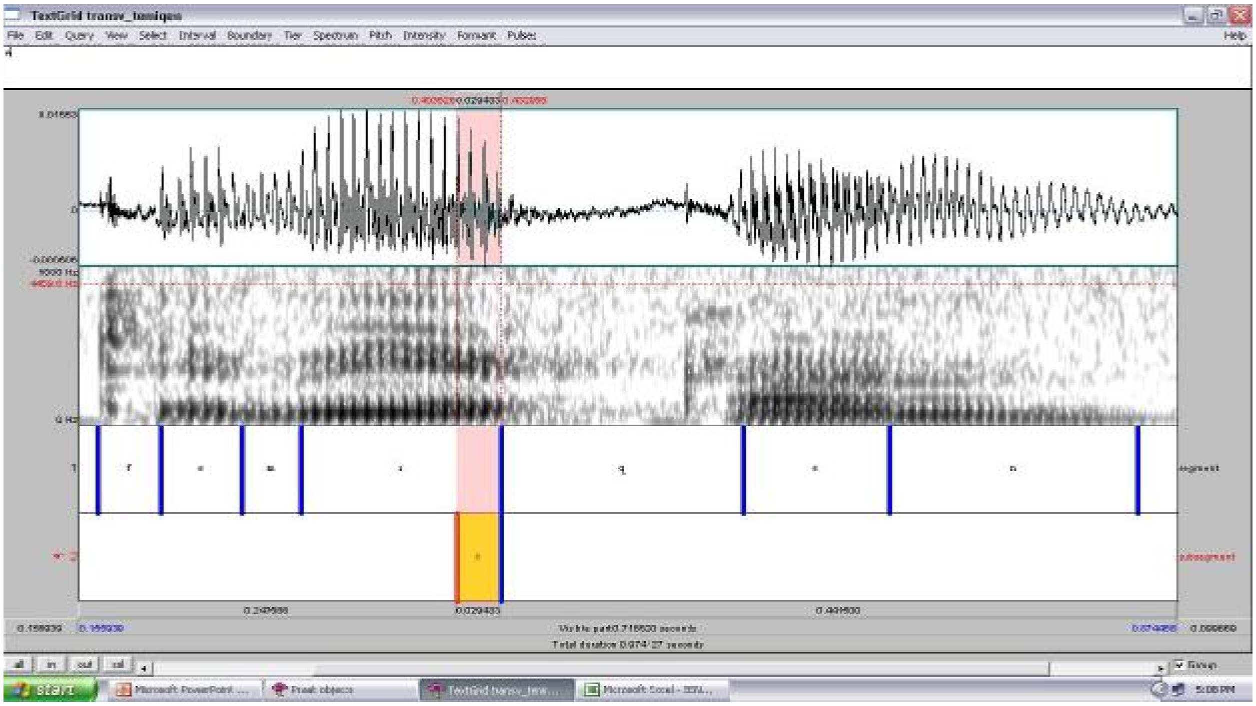

Figure 4. Transitional vowel in DEMIKEN – [t'əm'íqən]: 'get hit on the belly'.

Figure 5 is an example coded as 'transitional frication'. The word represented in the spectrogram is [híqət]: 'put something in the oven' as pronounced by Speaker 2. The portion of the word that is highlighted represents the transition between the vowel /i/ and the uvular stop. There is noise on this part of the spectrogram suggesting the presence of frication between /i/ and /q/. In this case, the vowel is somewhat transitional as well, indicated by unstable formants.

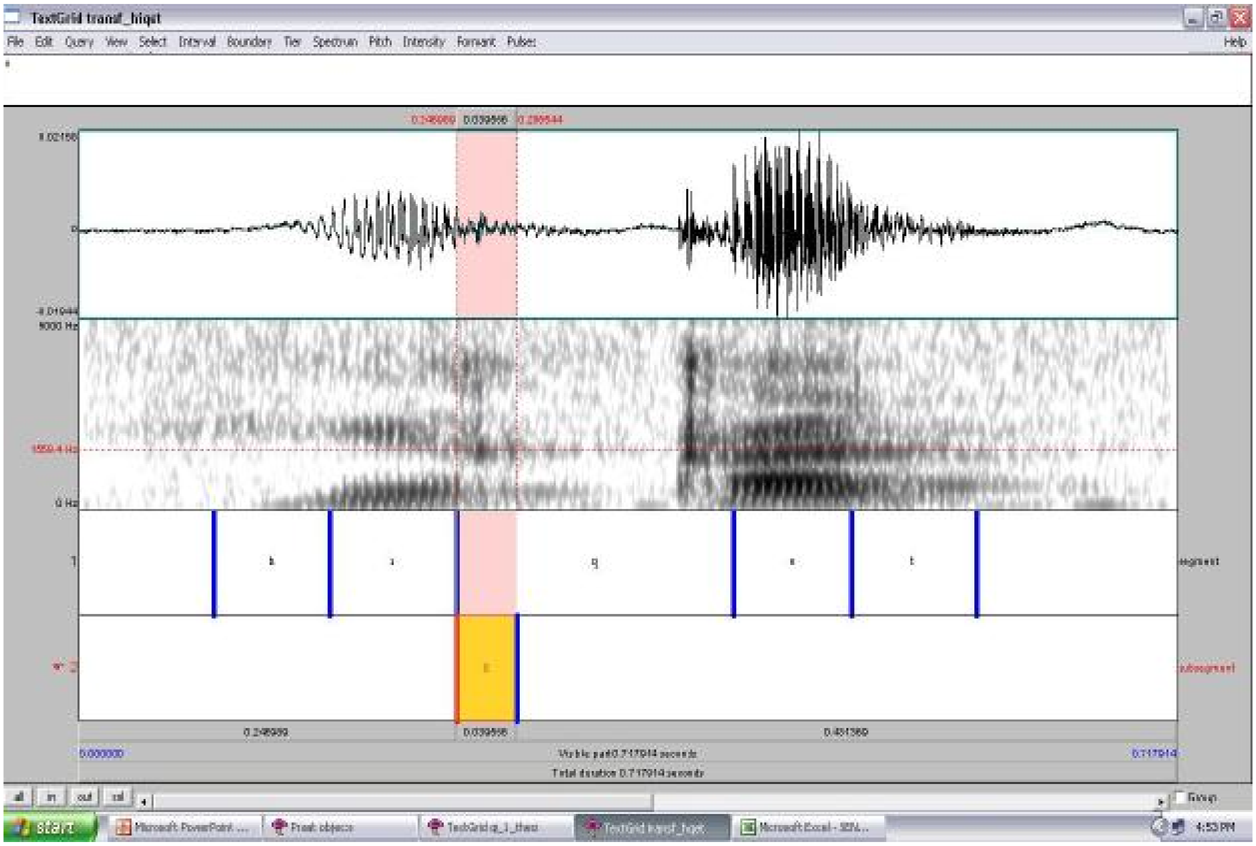

Figure 5. Transitional frication in HI<u>K</u>ET – [híqət]: ‘put something in the oven’.

Finally, Figure 6 is an example without any obvious sign of compromise, at least auditorily. The spectrogram is of the word [ʧíqəɴ]: ‘rock slide; land slide’ as pronounced by Speaker 1. The portion of the word that is highlighted is the vowel /i/. The formants are relatively stable with F1 lower (370 Hz at midpoint and 378 Hz at offset) and F2 slightly higher (2126 Hz at midpoint and 2088 Hz at offset) than the example in Figure 3. It seems that F1 in particular reflects our auditory judgment of “no effect” in Figure 6, as opposed to vowel retraction in Figure 3. The stable formants and lack of noise present on the spectrogram indicate that there is also no transitional element present between the vowel and the uvular.

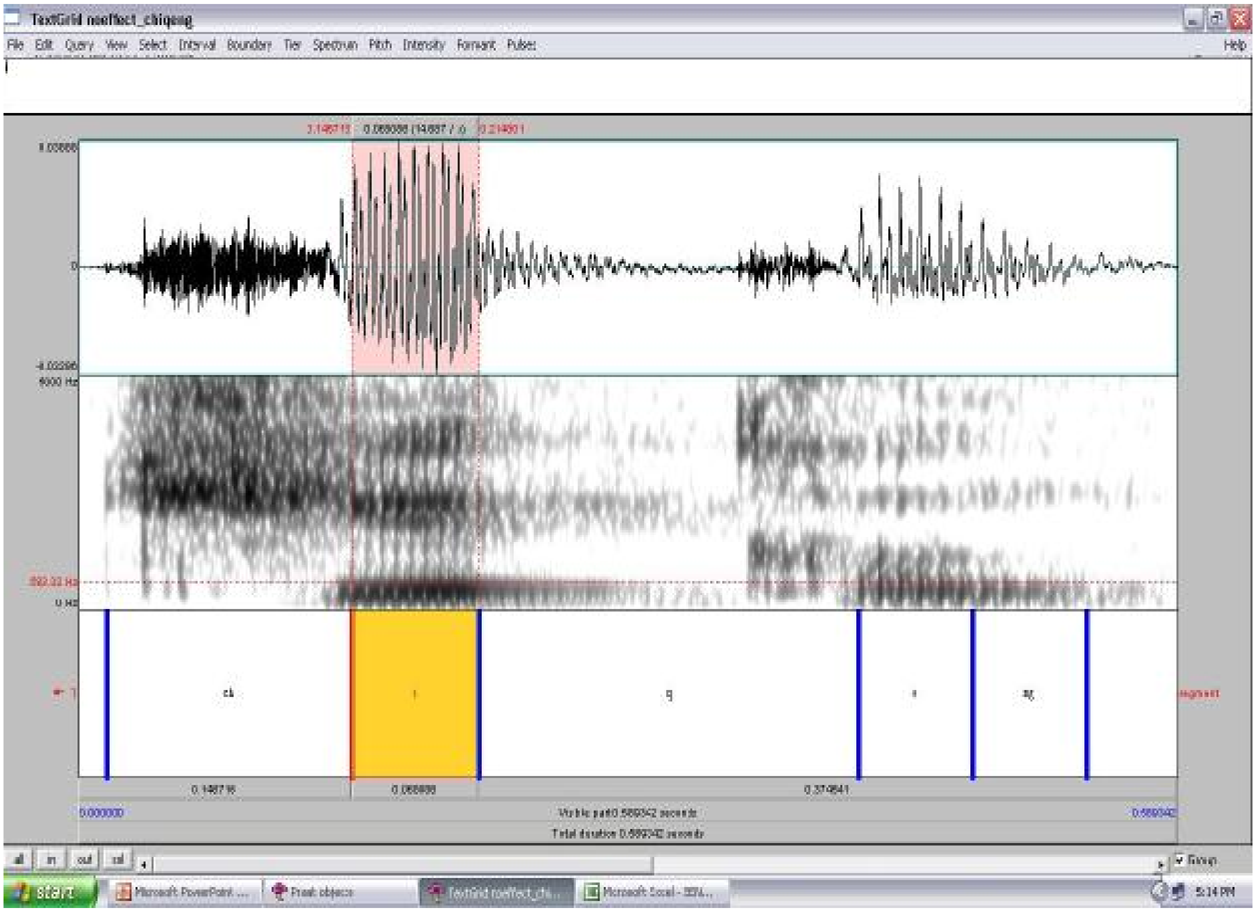

Figure 6. No obvious effect in ĆIKEN – [tʃíqəɴ]: ‘rock slide; land slide’.

The second method of analyzing the data was instrumental. The /i/ vowels adjacent to /q/ were measured in terms of first and second formant (F1 and F2) height and movement. This was done by measuring F1 and F2 at three points: 5%, 50% and 95% into the vowel. All measurements were automated using a Praat script. Manual measurements were also taken on a subset of tokens to ensure that the automated measurements were accurate. Instrumental measurements were used primarily to verify auditory impressions. For example, a vowel judged as retracted was expected to show relatively stable formants across measurement points, with a raised F1 and lowered F2 compared to unretracted /i/[11].

[11] Relative F1 and F2 heights were evaluated by comparing them to F1 and F2 values of /i/ in non-retracted contexts elicited previously (Leonard 2007). Unretracted /i/ values were averaged from 10 tokens in total (2 speakers x 5 tokens each).

3. Results.

Two sets of results are presented, corresponding to the two analysis methods: those from the auditory analysis first, followed by those from the instrumental analysis.

3.1. Auditory analysis.

Table 3 represents the strategies used in /qi/ sequences, merged across stress conditions. The number of tokens and percentages attested for each strategy is provided; the most common strategy is bolded. Overall in /qi/ sequences, vowel retraction was used significantly more than any other strategy ($\chi^2(5, 45) = 15.40$, $p < 0.01$), though its frequency of use differs somewhat between speakers: Speaker 1 used vowel retraction and a transitional vowel equally frequently (26.6% of tokens each), whereas Speaker 2 used primarily vowel retraction (45.5% of tokens). Note that other strategies were also used by both speakers. This indicates a vast amount of variability between and within each speaker, as is often the case with phonetic realization (see for example Pierrehumbert & Frisch (1996) on the pronunciation of glottalization in English).

Strategy	Overall		Speaker 1		Speaker 2	
	#	%	#	%	#	%
V retraction	**16**	**35.6**	**6**	**26.1**	**10**	**45.5**
Transitional V	7	15.6	**6**	**26.1**	1	4.5
Transitional F	4	8.9	2	8.7	2	9.1
Transitional F + V retraction	8	17.8	3	13.0	5	22.7
Transitional F + transitional V	8	17.8	4	17.4	4	18.2
No obvious effect	2	4.4	2	8.7	0	0
Total	45	100	23	100	22	100

Table 3. Strategies used in /qi/ sequences (V = vowel; F = frication).

Table 4 represents the strategies used in /iq/ sequences. In these sequences, transitional frication was used significantly more than any other strategy ($\chi^2(4, 28) = 17.71$, $p < 0.005$). Again there is significant variability in pronunciation, both within and across speakers: Speaker 1 most often used either transitional frication or vowel retraction (35.7% of tokens each), whereas for Speaker 2, the most common strategy was clearly transitional frication (64.3% of tokens).

Strategy	Overall		Speaker 1		Speaker 2	
	#	%	#	%	#	%
V retraction	6	21.4	**5**	**35.7**	1	7.1
Transitional V	4	14.3	1	7.1	3	21.4
Transitional F	**14**	**50**	**5**	**35.7**	**9**	**64.3**
Transitional F + V retraction	2	7.1	1	7.1	1	7.1
Transitional F + transitional V	0	0	0	0	0	0
No obvious effect	2	7.1	2	14.3	0	0
Total	28	100	14	100	14	100

Table 4. Strategies used in /iq/ sequences.

As illustrated in Tables 3 and 4, speakers differed somewhat from one another in the strategies they used in pronouncing both /qi/ and /iq/ sequences. Overall, Speaker 2 exhibited less variability than Speaker 1, in that his most common strategies were more frequent (reflected by higher percentages of use) than Speaker 1's most common strategies. Another difference between speakers is that Speaker 2 used transitional frication much more often than did Speaker 1, across both segmental positions. This difference is illustrated in Table 5, which summarizes the presence versus absence of transitional frication for both speakers.

Frication	Speaker 1		Speaker 2	
	#	%	#	%
Yes	15	40.5	21	58.3
No	22	59.5	15	41.7
Total	37	100	36	100

Table 5. Presence vs. absence of transitional frication by speaker.

Finally, only Speaker 1 exhibited tokens without any obvious conflict resolution strategy. At first blush this seems somewhat unusual; however Speaker 1 is a big-house speaker and may have been articulating his words more carefully than Speaker 2. This issue is discussed further in section 4.2.

Tables 3, 4 and 5 above present results merged across stress conditions. We now take a closer look at the effect of stress on conflict resolution strategy. Table 6 represents the strategies used in /qi/ and /iq/ conditions, in stressed position only. Results support the overall pattern observed above: vowel retraction is most common in /qi/ cases whereas transitional frication is most common on /iq/ cases. This result is not surprising, given that the majority of tokens elicited were in stressed position (see Table 2 above).

One point worth noting is that in stressed position, both speakers used transitional frication to a greater degree than in the overall results: in /qi/ cases, this is reflected by the increased percentages of strategies involving transitional frication (transitional frication: 11.1% in stressed position vs. 8.9% overall; transitional frication + vowel retraction: 22.2% in stressed position vs. 17.8% overall). In /iq/ cases, this is reflected primarily by the higher percentage of transitional frication cases (63.3% in stressed position vs. 50% overall).

Strategy	/qi/		/iq/	
	#	%	#	%
V retraction	**11**	**30.6**	3	13.6
Transitional V	6	16.7	1	4.5
Transitional F	4	11.1	**14**	**63.6**
Transitional F + V retraction	8	22.2	2	9.1
Transitional F + transitional V	6	16.7	0	0
No effect (?)	1	2.8	2	9.1
Total	36	100	22	100

Table 6. Auditory analysis stressed condition.

Table 7 represents the strategies used by both speakers in unstressed /qi/ and /iq/ positions. These results differ slightly more from the overall results than do those in stressed position. The most common strategy for the unstressed /qi/ was vowel retraction (55.6% of tokens). Unlike in stressed position though, vowel retraction was never accompanied by transitional frication. In the unstressed /iq/ position the articulatory strategy used by both speakers was either a transitional vowel (50% of tokens) or transitional frication accompanied by vowel retraction (50% of tokens), as opposed to simple transitional frication, as in the stressed /iq/ sequences.

Strategy	/qi/		/iq/	
	#	%	#	%
V retraction	**5**	**55.6**	0	0
Transitional V	1	11.1	**3**	**50**
Transitional F	0	0	0	0
Transitional F + V retraction	0	0	**3**	**50**
Transitional F + transitional V	2	22.2	0	0
No effect (?)	1	11.1	0	0
Total	9	100	6	100

Table 7. Auditory analysis unstressed condition.

Summarizing the effect of stress, /qi/ and /iq/ in stressed environments match the overall patterns, not surprisingly since they constitute the majority of tokens. In unstressed environments, the primary difference is in /iq/ sequences, which are pronounced with either a transitional vowel or with transitional frication accompanied by vowel retraction, unlike the stressed /iq/ for which simple transitional frication is most common.

3.2. Acoustic analysis.

The overall results of the auditory analysis show that vowel retraction is the most common strategy used in the /qi/ environment and transitional frication is the most common strategy used in the /iq/ environment (/qi/ → [qɪ]; /iq/ → [i^{x}q]). In this section we address two main questions. 1) Do the acoustic facts support the auditory distinction between retracted vowels and transitional vowels (in the /qi/ environment), and 2) do the acoustic facts support the auditory distinction between vowel retraction and transitional frication (in the /qi/ vs. /iq/ environments)? These two questions are particularly important to address given the auditory findings – see further explanations below.

To answer the first question, acoustic measurements of the vowel formants (F1 and F2) were taken in what were judged in the auditory analysis to be 'vowel retraction' cases vs. 'transitional vowel' cases. Only vowels in /qi/ position were included. This was because /qi/ was the position in which a majority of tokens were judged to have retracted vowels. This was therefore the position in which we wanted to assure ourselves that the acoustic results supported the auditory finding that vowel retraction was most common (as opposed to a transitional vowel). In total, 16 vowel retraction and 7 transitional vowel tokens were included (see Table 3). In the vowel retraction context we expected to observe stable formant measurements with a relatively high F1 and low F2. In the transitional vowel context we expected to observe unstable formants measurements, with F1 lowering and F2 rising away from /q/.

Results show that acoustic and auditory analyses match for Speaker 2 but not for Speaker 1. Table 8 provides mean F1 and F2 values at the onset, mid point, and offset of vowels judged to be retracted in the auditory analysis, for each speaker. Focusing on F1, Speaker 2 has a consistently raised F1[12], reflecting vowel retraction. Speaker 1 on the other hand has an F1 which is raised at its onset (adjacent to /q/) but lowers away from /q/, reflecting more a transitional quality. These acoustic results reflect the auditory analysis: Speaker 2 was judged to use vowel retraction most frequently (reflected by relatively stable, raised mean F1), and judgments were relatively easy to make in listening to his speech. In contrast, Speaker 1 was judged to use vowel retraction and a transitional vowel equally frequently (leading to a mean F1 that is relatively unstable and less raised), and judgments (vowel retraction vs. transitional vowel) were often much more difficult to make. We return to the issue of making auditory judgments in section 4.2 below. Note

[12] This is relative to /i/'s F1 in non-uvular context; see Table 13 for baseline /i/ values.

that the trajectories of F2 do not show as clear a pattern as those for F1. This is also discussed further in section 4.

Speaker	F1 onset	F1 middle	F1 offset	F2 onset	F2 mid	F2 offset
1	400 (50)	349 (20)	341 (10)	2049(85)	2072 (79)	2041 (135)
2	425 (35)	401 (28)	390 (27)	2038 (121)	2075 (65)	2060 (85)
Mean	415 (42)	382 (36)	372 (33)	2042 (106)	2073 (68)	2053 (103)

Table 8. F1 and F2 values at onset, midpoint, and offset of 'vowel retraction' (/qi/).

Table 9 summarizes mean F1 values at onset, midpoint, and offset of vowels judged to be transitional. Note that Speaker 2 has a single token that was analyzed auditorily as a transitional vowel (see Table 3 above), hence no standard deviation values. Again, the auditory judgments are reflected in the acoustic data in the case of Speaker 2 but not Speaker 1: Speaker 2's formants are unstable, with F1 lowering away from the /q/ and F2 rising away from it, as we would expect for a transitional vowel. Speaker 1's F1 follows the expected pattern, though somewhat less dramatically than Speaker 2's; however, his F2 remains stable throughout the vowel. We return to F2 values and their movement in section 4.2.

Speaker	F1 onset	F1 middle	F1 offset	F2 onset	F2 mid	F2 offset
1	393 (19)	340 (19)	336 (36)	2071 (50)	2096 (87)	2091 (120)
2	428	358	351	1937	2084	2146
Mean	398 (22)	343 (19)	338 (34)	2052 (68)	2095 (80)	2099 (112)

Table 9. F1 and F2 values at onset, midpoint, and offset of 'transitional vowel' (/qi/).

Figures 7 and 8 provide a visual comparison of vowels judged to be retracted vs. transitional. In these figures, only Speaker 2's data are plotted, since Speaker 1's acoustic data did not match the results of the auditory analysis very well. Figure 7 plots F1 of the one transitional vowel in the data (squares) and the average F1 of the ten retracted vowels (diamonds), at three points in time: vowel onset, vowel midpoint, and vowel offset. As can be seen in Figure 7, F1 is relatively high at its onset (adjacent to the uvular) for both retracted and transitional vowels. For both vowels, F1 lowers away from the uvular, but it does so in a much more pronounced way for the transitional vowel than for the averaged retracted vowel, indicating that this vowel is indeed more transitional than the retracted vowels, and that its F1 at offset is much closer to that of a typical /i/ than that of the retracted vowels.

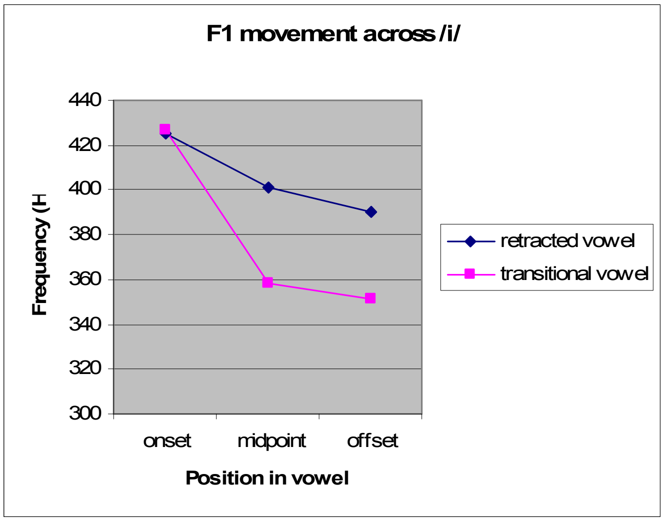

Figure 7. Speaker 2: F1 movement in */i/* in vowels coded as retracted vs. transitional.

To quantify the transitional element of the vowels, the difference between onset and offset values for F1 (delta-F1) was calculated in each case: 77 Hz for the transitional vowel vs. an average of 35 Hz for the retracted vowels. Normally one could perform a t-test to determine whether or not delta-F1 is significantly different in retracted vs. transitional vowels. However, because only one vowel was judged to be transitional, it was not possible to statistically test for significance.

Figure 8 is similar to Figure 7, but plots F2 of the one transitional vowel (squares) and the average F2 of the ten retracted vowels (diamonds). Again, data are included only for Speaker 2. Figure 8 shows that F2 is relatively low and stable for the averaged retracted vowel, as expected. For the transitional vowel, F2 is much lower at its onset (adjacent to the uvular) than it is for the retracted vowel, but rises steeply to a much higher offset value, again moving up into the range of a typical */i/* vowel.

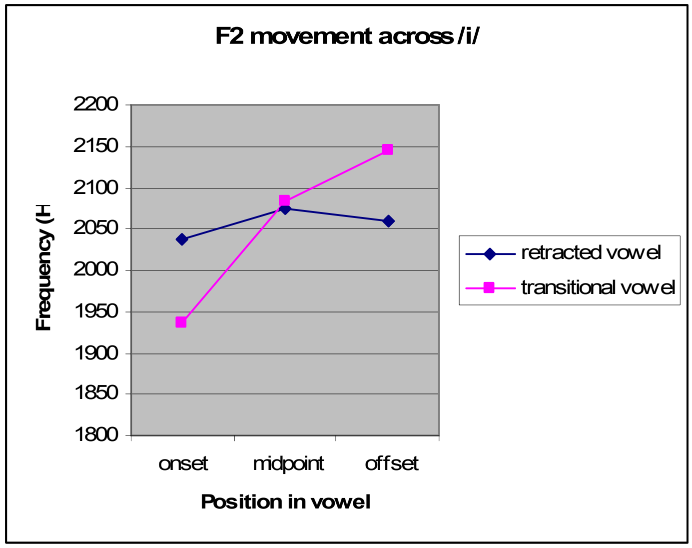

Figure 8. Speaker 2: F2 movement in */i/* in vowels coded as retracted vs. transitional.

Delta-F2 for the transitional vowel is 209 Hz vs. an average of 22 Hz for the retracted vowels. Again, a statistical test of delta-F2 would not yield meaningful results here since there is only one transitional vowel. Overall though, formant values do indicate a clear difference in formant movement (both F1 and F2) between the transitional vowel and the averaged retracted vowels.

The second question asked whether or not the acoustic facts supported the auditory distinction between vowel retraction in the /qi/ environment vs. transitional frication in the /iq/ environment. To address this question, cases judged as ‘vowel retraction’ in /qi/ position were compared to cases judged as ‘transitional frication’ in /iq/ position, in terms of their F1 and F2 movement away from /q/. As discussed and illustrated above (see Figures 7 and 8), vowels in /qi/ position judged to be retracted were expected to exhibit stable formants, with a relatively high F1 and relatively low F2. Vowels in /iq/ position judged to have transitional frication (but no vowel effect) were also expected to have relatively stable formants, but with a relatively low F1 and relatively high F2, more typical of /i/ vowels. In total, 16 vowel retraction tokens and 14 transitional frication tokens were considered (see Tables 3 and 4).

Again, results showed a match between acoustic and auditory analyses only for Speaker 2 and as we shall see, even for Speaker 2 the match was not as clear as one might have expected. Table 8, above, provides F1 and F2 values at onset, midpoint and offset for vowel retraction cases in /qi/ position. Table 10 provides F1 and F2 values for transitional frication cases in /iq/ position. For Speaker 2, F1 is lower overall in transitional frication cases than in vowel retraction cases, although in both cases it rises towards the /q/, indicating that there is some degree of vowel retraction even in the transitional frication cases. Second formant values are again relatively high, as they were for the vowel retraction cases (Table 8). For Speaker 1, both F1 and F2 are very similar across cases, indicating no clear distinction between vowel quality in vowel retraction vs. transitional frication cases.

Speaker	F1 onset	F1 middle	F1 offset	F2 onset	F2 mid	F2 offset
1	349 (32)	336 (22)	341 (32)	2059 (154)	2109 (58)	1950 (135)
2	333 (45)	349 (47)	382 (72)	1977 (237)	2019 (157)	1913 (158)
Mean	339 (40)	344 (39)	367 (62)	2006 (208)	2051 (135)	1926 (146)

Table 10. F1 and F2 values at onset, midpoint, and offset of 'transitional frication' (/iq/).

Figure 9, similar to Figures 7 and 8, plots average F1 values at three points in the vowel: onset, midpoint, and offset. Again, only Speaker 2's data are included since Speaker 1's data do not match the auditory analysis. Vowel retraction cases in /qi/ position (diamonds) are compared to transitional frication cases in /iq/ position (squares). Looking at the vowel retraction cases (repeated from Figure 7), one can see that F1 is high at onset, adjacent to /q/ and then lowers somewhat, remaining relatively high, indicative of vowel retraction. As mentioned above, F1 is lower overall in the transitional frication cases than in the vowel retraction cases, as expected. Note however that there is some movement upwards towards the /q/, indicated by a rising F1 from onset to offset[13]. Although F1 is more typical of the /i/ vowel in the transitional frication cases than in the vowel retraction, it is still somewhat transitional.

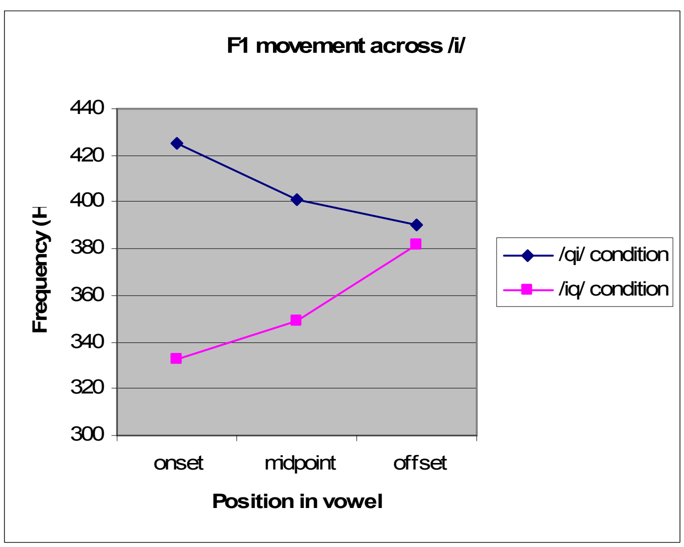

Figure 9. Speaker 2: F1 movement in /qi/ (retracted vowel) vs. /iq/ (transitional frication).

[13] F1 movement in /iq/ position is the mirror image of F1 movement in /qi/ position, because the uvular is on opposite sides of the vowel in these two positions.

A two-tailed t-test shows that F1 values adjacent to /q/ (onset in /qi/ cases and offset in /iq/ cases) do not actually differ significantly from one another. This is possibly an effect of a small number of tokens. F1 values are significantly different at their midpoints ($t(17) = 3$, $p < 0.01$) and at their furthest points from /q/ (offset for /qi/ cases and onset for /iq/ cases) ($t(17) = 3.4$, $p < 0.005$), with values significantly lower in /iq/ condition indicating that /i/ is less retracted overall in transitional frication cases than in vowel retraction cases, as expected.

The measurements of the F2 movements across /i/ do not support the distinction between retracted vowel and transitional frication. These are illustrated in Figure 10, the layout of which corresponds to that of Figures 7-9. For consistency, here too only Speaker 2's data are included. In the vowel retraction case (/qi/ environment), F2 is relatively stable and high. In the transitional frication cases, F2 drops substantially immediately preceding the uvular, again indicating that in addition to transitional frication, some kind of transitional vowel is also occurring which was not detected in the auditory analysis. Most puzzling is the fact that F2 has higher values overall in what were judged as vowel retracted cases than it does in what were judged as transitional frication cases, which is the opposite pattern from that expected (as illustrated in Figure 3 as well).

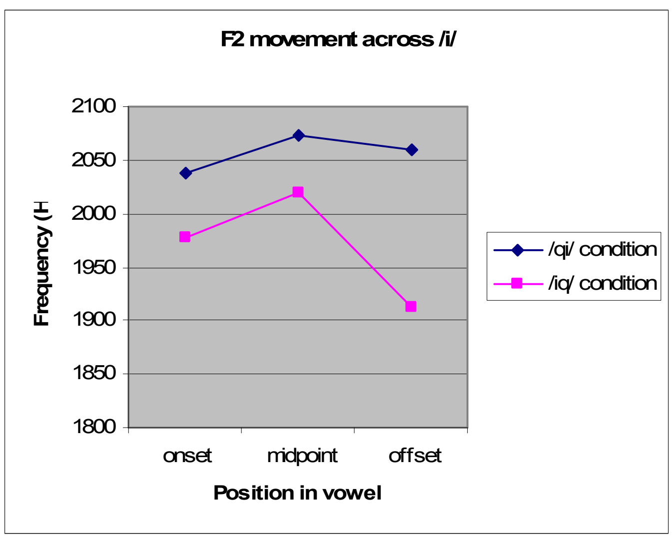

Figure 10. Speaker 2: F2 movement in /qi/ (retracted V) vs. /iq/ (transitional frication).

Since the patterns for F2 are contrary to expected, no statistical tests were done to verify the effects.

3.3. Summary of results.

In sum, the auditory results indicate that the more usual strategy used in /qi/ cases is vowel retraction and in /iq/ cases a transitional fricative. The acoustic measurements mostly support these findings for Speaker 2: in /qi/ environments, vowel retraction cases show more stable formants (including a higher F1 and lower F2) than transitional vowel cases, as expected (Figures 7 and 8). In vowel retraction cases (/qi/ environment) vs. transitional frication cases (/iq/ environment), F1 is higher in vowel retraction cases, although in both cases a fair amount of formant movement is observed. As for F2, it patterns in a way opposite to predictions. The overall results for Speaker 1 did not show a clear match between auditory and acoustic measurements. Possible ways to explain this mismatch will be addressed in the following section.

4. Discussion.

This section focuses on two areas of discussion: how the SENĆOŦEN facts fit with facts from other languages of the Pacific Northwest, and how to reconcile the findings of the auditory and acoustic analyses.

4.1 SENĆOŦEN and other Pacific Northwest languages.

Discrepancies between the auditory and acoustic analyses aside, the overall results are as follows: the main factor contributing to how *uvular stop + high front vowel* sequences are pronounced is position: in /qi/ sequences we get vowel retraction leading to [qɪ] whereas in /iq/ sequences we get a transitional fricative, leading to something between [i^{x}q] and [i^{χ}q]. In terms of Gick & Wilson's (2006) typology outlined in section 2, SENĆOŦEN patterns with Nuu-chah-nulth as a language of type C, with asymmetrical conflict resolution. Interestingly in the case of SENĆOŦEN, the transitional element in /iq/ sequences is consonantal (a fricative) rather than a vocalic element, as in Nuu-chah-nulth.

Table 11 summarizes the ways in which /qi/ and /iq/ sequences are pronounced in a sampling of Central Salish languages. Our findings aside (first row), the information provided is based on auditory descriptions found in existing grammars of these languages. Note that /i/ in SENĆOŦEN is relatively retracted compared to /i/ in other languages, even when not adjacent to a uvular consonant (elsewhere condition. The symbol used here is nonetheless [i], in agreement with previous descriptions of the language.

Language	/qi/	/iq/	/i/ elsewhere
SENĆOŦEN Current findings	[qɪ]	[iˣq]	[i]
SENĆOŦEN[14] (Montler 1986)	[qɪ]	[ɪq]	[i]
Musqueam (Suttles 2004)	[qe]	[iᵊq]	"low [i] or high [e]"
Cowichan (Kava 1967)	[qɪ] ~ [qe]	[iᵊq]	[i] ~ [ɪ]
Mainland Comox (Davis 1978)	[qe]	[iᵊq]	[ɪ]
S<u>k</u>w<u>x</u>wú7mesh (Dyck 2004)	[qej]	[eq]	[i] (unstressed [e] (stressed)
Sliammon (Blake 2000)	[qɛ]	[ɛq]	[i] ~ [ɛ] ~ [e]

Table 11. The pronunciation of /qi/ and /iq/ sequences in Central Salish languages.

Glancing over Table 11, the majority of languages sampled exhibit an asymmetrical conflict resolution strategy, with vowel retraction in /qi/ sequences and a transitional element in /iq/ sequences. The two exceptions are S<u>k</u>w<u>x</u>wú7mesh (Squamish) and Sliammon; a possible explanation for these exceptions is their proximity to Interior Salish languages which – as we shall see – generally exhibit symmetrical conflict resolution strategies. Interestingly Nuu-chah-nulth, a Wakashan language spoken on the west coast of Vancouver Island, exhibits an asymmetrical conflict resolution strategy similar to that of Central Salish languages. Possibly then, the strategy used is an areal phenomenon rather than a genetic one.

Table 12 summarizes the way /qi/ and /iq/ sequences are pronounced in Interior Salish languages. Again, the information provided is based primarily on auditory analysis found in grammars of these languages. An exception is St'át'imcets, as studied articulatorily (with ultrasound) and acoustically by Namdaran (2006).

[14] Montler's (1986) observations are based on work with a single female speaker. As Table 11 illustrates, they do not correspond to the observations reported in section 3. This discrepancy has also been found for other phonetic properties of the language, which are currently being explored further.

Language	/qi/	/iq/	/i/ elsewhere
St'át'imcets (van Eijk 1997; Shahin 2002)	[qej]	[ɛq]	[i] ~ [ɪ] ~ [ɛ]
St'át'imcets (Namdaran 2006)	[qɛ]	[ɛq]	[i] ~ [ɪ]
Spokane (Black 1996)	[qᵊi]	[iᵊq]	[i]
Nlhe7kempxcin (Thompson & Thompson 1992)	[qe] (~ [qᵊi])	[eq] (~ [iᵊq])	[ɪ]

Table 12. The pronunciation of /qi/ and /iq/ sequences in Central Salish languages

In contrast to Central Salish languages, Interior Salish languages seem to have primarily symmetrical conflict resolution strategies, with either vowel retraction in both /qi/ and /iq/ contexts, as Namdaran (2006) observed in St'át'imcets, or with a transitional element in both contexts, as in Spokane.

Recall from the introduction the two questions that were raised by Gick & Wilson's (2006) factorial typology: 1) are all languages in the typology actually attested, and 2) are they attested with equal frequency? In answer to the first question, Gick & Wilson found that no language had yet been attested of type A, in which /qi/ and /iq/ sequences were pronounced [qᵊi] and [iᵊq] respectively. While SENĆOŦEN does not exhibit this pattern, other Salish languages seem to do so, namely Spokane and Nlhe7kempxcin (both in the Interior Salish sub-family). Further analyses of these two languages, auditory and instrumental, will hopefully confirm whether or not they are truly of type A.

In answer to the second question, Gick & Wilson suggest that conflict resolution strategies are more often asymmetrical than symmetrical. The Salish facts indicate that symmetrical conflict resolution, while possibly less common than asymmetrical resolution, is certainly attested across languages. Indeed, the Interior Salish languages have primarily symmetrical conflict resolution strategies, though they differ in the precise nature of these strategies (vowel compromise vs. transitional element). Based on facts of Salish languages then, conflict resolution strategies vary on a language-specific basis. Interestingly, of the four language types predicted by Gick & Wilson, type D [qᵊi; ɪq] is the only one not attested in any Salish language so far documented. This fact is discussed further in section 4.2 below.

One further point worth noting with respect to Gick & Wilson's typology is that in the languages considered here, if a segment is compromised it seems to always be the vowel. For example, we get [qɪ] for /qi/, rather than [ki] – in which the consonant has been compromised. As mentioned in the introduction (section 2), this is conceivably due to the need to preserve contrast in the languages considered. In most Salish languages, velar and uvular stops /k/ and /q/ are contrastive, whereas high front vowels /i/ and /ɪ/ are not. Therefore, if a segment must be compromised, the vowel is the obvious choice since it will not interfere with lexical contrasts. The prediction is that in a language *without* contrastive velar and uvular stops and *with* contrastive high front vowels, the consonant will be compromised rather than the vowel. Some support for this prediction is found in English, in which we get consonant compromise (rather than vowel compromise) in sequences of velar consonants and front high vowels. Take for example the pronunciation of ‘keep’ [k̟ʰip] vs. ‘coop’ [kʰup]: in ‘keep’ the [k̟] is fronted because of the following high front vowel, whereas in ‘coop’ it is not. Another way of pronouncing /ki/ sequences might be to compromise the vowel by retracting it slightly (/kip/ → [kɪp]) so as to avoid advancing the [k] sound. In the English perceptual space[15], /k/ does not have any close neighbours (e.g. an underlying uvular or palatal voiceless stop), whereas /i/ does: /ɪ/. As a result, compromising /k/ rather than /i/ minimizes the risk of neutralizing a lexical contrast. English facts then indicate that the choice to compromise the vowel vs. the consonant may well depend on the consonant and vowel inventories of the language in question.

4.2 Auditory vs. acoustic analyses.

Recall from section 3 that an acoustic analysis of vowel formants was conducted to verify two distinctions that were made based on auditory impressions: 1) the distinction between vowel retraction and a transitional vowel in /qi/ sequences and 2) the distinction between vowel retraction in /qi/ sequences and transitional frication in /iq/ sequences. For both of these distinctions, the acoustic analysis matched the auditory analysis only for Speaker 2, and even for Speaker 2 the match was not as clear as one might have expected (see Figure 10). The question is: why is there not more agreement between acoustic and auditory analyses, particularly for Speaker 1?

One point worth mentioning in the context of the mismatch between auditory and acoustic analyses for Speaker 1 is that his data were relatively difficult to code, even auditorily. Speaker 1 is a big-house speaker, with a relatively formal speech register. One possible effect of this register is that his speech is pronounced in a careful manner, leading to less co-articulatory effects overall and consequently to more difficulty in determining what strategies are being used.

Another point worth considering is more general: the SENĆOŦEN data were not as easy to code as in some other languages (e.g. Nuu-chah-nulth – see Shank & Wilson 2000), and this is likely because /i/ is relatively retracted in *all* contexts in SENĆOŦEN. Table 13 provides F1 and F2 values for the vowel labeled as /i/ across a sample of Pacific

[15] See Flemming (2004) for a discussion of sound inventories and perceptual space.

Northwest languages. Also included are formant values for /i/ and /ɩ/ in American English (male speakers), as summarized in Kent and Read (2002).

Language	F1	F2
SENĆOŦEN (Leonard 2007)	381 (23)	1987 (84)
Klallam (Montler 1998)	315	2031
Montana Salish (Flemming et al. 1996)	349	2062
St'át'imcets (Namdaran 2006)	404	2344
Nuu-chah-nulth (Shank & Wilson 2000)	364	2191
/i/ (American English – Kent & Read 2002)	294 (26)	2275 (68)
/ɩ/ (American English – Kent & Read 2002)	416 (17)	1923 (99)

Table 13. First and second formants of /i/ across Pacific Northwest languages.

As Table 13 shows, the second formant of /i/ in SENĆOŦEN is particularly low compared to that of /i/ in other languages, matching more closely that of American English [ɪ]. In fact, the F2 baseline values for /i/ (based on Leonard 2007) are even lower than those reported in this paper for /i/ in uvular context (though probably not significantly so). Assuming that SENĆOŦEN /i/ is indeed more retracted than in other neighbouring languages, it is likely that in SENĆOŦEN, there is simply less of a conflict between /q/ and /i/ than there is in other languages, explaining why the conflict resolution strategies are not as clear.

Taking this idea further, the vowels that were noted as being retracted in the auditory analysis may have simply been standard SENĆOŦEN /i/s, rather than allophones specific to the uvular context. If this is the case, then vowel retraction may not be very important as a conflict resolution strategy for /qi/ sequences, and the only robust strategy employed in the language is transitional frication in /iq/ sequences.

Why would a conflict resolution strategy be required only in /iq/ sequences, but not in /qi/ sequences? A possible explanation lies in the ease with which the tongue retracts vs. advances. The genioglossus is primarily responsible for tongue advancement, as required in /qi/ sequences. As for tongue retraction, the musculature depends on the precise movement involved: the styloglossus is the primary muscle engaged in tongue raising (uvularization), whereas the hyoglossus takes on this role in tongue backing (pharyngealization). It is not yet known whether SENĆOŦEN /q/ is better described as uvularized or pharyngealized. In either case, it seems possible that because of the different muscles involved, retraction of the tongue from an advanced position is articulatorily more difficult than advancement of the tongue from a retracted position[16]. This may explain why some kind of conflict resolution strategy would be required in /iq/ sequences but not /qi/ sequences: given the underlyingly retracted nature of /i/ in

[16] J.H. Esling and E. Vatikiotis-Bateson, personal communication.

SENĆOŦEN, only in the /iq/ cases is the articulatory conflict sufficient to require resolution, i.e. a transitional element.

Recall from above that of the four language types predicted by Gick & Wilson, type D [qᵊi; ɪq] is the only one not attested in any Salish language that we have considered so far. This fact may be another reflection of articulatory ease: if /qi/ sequences are indeed easier to pronounce than /iq/ sequences, then this might explain why, to the extent that transitional elements appear anywhere, it is in /iq/ sequences and *not* in /qi/ sequences.

Another explanation for this gap comes from the literature on syllable-based asymmetries in articulatory timing. Several studies have shown that in segments consisting of two or more oral gestures, the gestures tend to be synchronous in onset position, whereas in coda position the more anterior gesture tends to precede the more posterior one (Krakow 1989, 1993; Brown & Goldstein 1992, 1995; Sproat & Fujimura 1993; Gick 2003; Gick et al. 2006). This fact has been attributed to perceptual recoverability (Mattingly 1981; Silverman & Jun 1994; Silverman 1997; Byrd 1994, 1996a, b; Wright 1996; Kochetov 2002, 2006; Chitoran et al. 2002): sounds are more difficult to perceive syllable-finally than syllable-initially; to ease perception syllable-finally, the gestures are "stretched out", often leading to a transitional element. Given the literature on perceptual recoverability, it seems likely that languages of type D (qᵊi; ɪq) do not exist because for perceptual reasons, transitional elements tend to be inserted preceding coda consonants rather than following onset consonants.

Teasing apart articulatory and perceptual explanations of the lack of a type D language in the Salish family is beyond the scope of this paper, but is an interesting topic for future research.

5. Conclusion.

This paper reports on an experiment designed to explore which conflict resolution strategies are used to pronounce /qi/ and /iq/ sequences in Salish languages. In SENĆOŦEN, vowel retraction is used in /qi/ sequences, whereas transitional frication is used in /iq/ sequences. This pattern fits nicely with the facts of other Central Salish languages, most of which show similar asymmetrical conflict resolution strategies, in contrast with the Interior Salish languages which show symmetrical strategies. Together, the Salish language facts shed important light on Gick & Wilson's (2006) language typology with respect to conflict resolution strategies.

The discrepancies between auditory and acoustic analyses point to an important area of future research. Recall that almost all of the Salish language facts presented in the discussion (Tables 11 and 12) were based on auditory impressions. From these facts, the patterns seem relatively straight-forward. If the SENĆOŦEN study is any indication though, instrumental analyses of these same languages may well yield less clear results. The question of how to relate auditory and acoustic analyses to one another, and of how much weight to place on each in making judgments on the phonetic nature of sounds, is an important one to consider, particularly given that phonetic descriptions of languages are increasingly based on instrumental analysis.

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Appendix

Dave Elliott Alphabet with Phonetic Equivalent[17]

DEA	*APA*	*IPA*
A	e	æ
Á	e	e
	ey	ej
B	p̓	p’
C	k	k
	k^w	k^w
D	t̓	t’
E	ə	ə
H	h	h
I	i	i
Í	ay~əy	aj~əj
J	č̓	tʃ’
K	q̓	q’
	q̓^{w}	q’^{w}
K̲	q	q
Ḱ	q^w	q^w
L	l	l
	ł	ɬ
M	m	m
N	n	n
O	a	ɑ
P	p	p
Q	k̓^{w}	k’^{w}
S	s	s
T	t	t
U	u~əw	u~əw
W	w	w
W̲	x^w	x^w
X	x̣	χ
X̲	x̣^{w}	χ^w
Y	y	j

[17] DEA=Dave Elliott Alphabet, APA=Americanist Phonetic Alphabet, IPA=International Phonetic Alphabet