The status of external sandhi in Cree

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1. Introduction

The Cree language has a set of vowel deletion and coalescence processes that apply at word boundaries. These processes seem to be perfect examples of the kind of post-lexical phonological rule which has led some researchers to propose complicated extensions to the theory of phonology. In this paper, I argue that Cree sandhi is not a true phonological rule, but is the kind of gradient phenomenon which can be handled by a number of existing theories of phonetics and the phonetics-phonology interface. As Cree sandhi joins the growing list of apparent phonological rules which are better assigned to the phonetic domain, it lends support to the hypothesis that phonology is categorical and lexical, and that post-lexical phonology need not exist.

1.1 Cree background

Cree (an Algonquian language spoken in much of Canada) has an essentially triangular vowel system with length distinction. There are three short vowels, conventionally written *i*, *a*, and *o*, though *o* in fact ranges between mid and high. Each short vowel has a long counterpart, conventionally written with a circumflex accent. There is in addition a long *ê*.

(2) Cree vowel system

short	i		o
		a	
long	î		ô
		ê	
		â	

Cree has optional processes that affect vowels that meet across a phonological word boundary. Although it is the phonological reality of these processes that is at issue in this paper, I will describe them in this section as if they were absolute and unquestionable, without the liberal sprinkling of the word "apparently" that strict accuracy would call for.

In the most general case, a short word-final vowel can be deleted. The following word-initial vowel, if it is short, will undergo compensatory lengthening. As a special case, word-final *a* and word-initial *i* will coalesce into long *ê*, rather than the expected *î*. Wolfart's (1973) initial description of these processes is given in (3).

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(3) $\breve{V}_1 + V_2 \rightarrow \bar{V}_2$
a + i → ê

As another special case, a word-final short o will delete and cause compensatory lengthening on the following vowel, but will continue to be realized as labialization on the preceding consonant.

Some examples from Minde (1987) are given in (4-6). The first line gives an idealized representation of the sentence, giving each word in the canonical form it has as the output of lexical phonology. The second line gives the actual sentence, as transcribed by the editors, showing the effects of sandhi.[1]

(4) êwak**o** anim**a** êkos**i** ê - kî - isi - pimâcihocik kayâs ayisiyiniwak
êwak**w** ânim êkos ê - kî - isi - pimâcihocik kayâs ayisiyiniwak
'That is how that people made a living long ago.'

This paper will concentrate on two particular kinds of sandhi: i) the result of short *a* and long *ê* meeting across a word boundary, as illustrated in (5), and ii) the result of the complementizer particle *kâ* coalescing with a following short *i*, as illustrated in (6).

(5) napêwasikana mân**a** ê - kî - osîhâcik
napêwasikana mân ê - kî - osîhâcik
'They used to make men's socks.'

(6) ê-kî-âpacihtât mâna ânima âya, 'astinwân' **kâ-i**siyîhkâtêk
ê-kî-âpacihtât mân ânim âya, 'astinwân' **k-ê**siyîhkâtêk
'...she used to use "sinew", as it is called.'

1.2 Theoretical implications

A significant amount of work has gone into making phonological theory capable of dealing with between-word processes of the kind illustrated by Cree external sandhi. Kaisse (1985), for example, argues for a typology of postlexical rules, distinguishing between P1 rules (which crucially need to refer to morphological or syntactic properties or constituents) and P2 rules (the more familiar kind of postlexical rules which apply without regard for syntax). There has been an understandable reluctance to accept the theoretical consequences of P1 rules. Condoravdi (1990) reanalyzes sandhi rules in Greek, one of Kaisse's central examples, so that they no longer need to refer to syntactic consituency but simply to constituents of the prosodic hierarchy (though crucially a prosodic hierarchy with a level between that of the word and phrase). Hayes (1990) offers a proposal for "pre-compiled phrasal phonology", in which the effects of phrasal rules can be computed entirely within the lexical component, leaving the postlexical component just the job of choosing the appropriate lexically derived representation for each word.

A more radical approach to the problems posed by sandhi rules is to question whether

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[1] Word-by-word glosses for these examples are:
(4) aforementioned that:one in:that:way COMP - PAST - thus - they:made:a:living long:ago people
(5) men's:socks HABIT COMP - PAST - they:made
(6) COMP - PAST she:used HABIT that the:one, sinew COMP - it's:called

the phenomena really exist or, more precisely, whether the phenomena are really better handled by the categorical devices of phonology rather than by the independently needed gradient devices of phonetics. Kaisse (1985: 115, fn 5-6) acknowledges that Greek sandhi is optional and often partial. Examining the phonetic facts of another famous post-lexical rule, palatalization sandhi in English (e.g., mɪs ju → mɪʃu), Zsiga (1995) finds that a phonetically-based explanation (overlapping gestures in the style of Articulatory Phonology) is more empirically adequate than one involving a phonological rule that changes *s* to *ʃ*. Similar results can be found in the area of vowel sandhi. Traditional phonological accounts of Igbo give identical treatment to intra-word [ATR] harmony (causing, e.g., the alternation of the imperative suffix in *ṣi-ạ* 'tell!' vs. *si-e* 'cook!') and inter-word vowel assimilation (e.g., *nwoke a* → *nwoka a* 'this man'). Both are assumed to be results of feature spreading, differing only in whether they apply at the lexical or postlexical level. But, as Zsiga (1997) shows, while intra-word harmony does have the kind of result we would expect from the application of a categorical phonological rule, the phonetic results of inter-word assimilation continue to show the effects of the apparently "deleted" vowel, in a manner which is again better explain by a gestural account than by a phonological rule.

In his response to Zsiga (1995), Scobbie (1995) poses the question: "What do we do when phonology is powerful enough to imitate phonetics?" It is worthwhile to explore more restrictive models, where phonology does not have the power to imitate phonetics. One of the simplest models of the phonology/phonetics interface has an absolute division between categorical and gradient: all categorical changes are made by phonological rules in the lexical component, while all gradient changes are the result of well-defined phonetic processes (e.g., gestural overlap) that affect the articulatory implementation of the phonological surface representation. While this hypothesis may eventually prove too strong, it is useful to entertain it for the time being, if only as the motivation for a search for counterexamples. The most convincing kind of counterexample would be a case of a categorical postlexical rule — a rule which shows all the signs of the absolute change expected of phonological rules but which could not possibly have applied during the lexical component. If Cree external sandhi really is as it has been described, it would be such a counterexample.

In this study, I look at whether the external sandhi phenomena of Cree are categorical, and thus inconsistent with the simple division of labour described above or whether it is gradient, like vowel assimilation in Igbo, and would be better handled by a theory of phonetics. In short, is the first vowel really deleted?

2. Method

The text analysed is an extract from an autobiographical narrative (Minde 1997) told by Emma Minde, a native speaker of Plains Cree. The linguist present and recording the narrative was Freda Ahenakew, also a native speaker of Plains Cree. The text was transcribed by Ahenakew and H.C. Wolfart, whose decisions as to which vowels have undergone apparent sandhi are followed here.

The analysis focuses on two complementizer particles used at the beginning of the verbal complex in subordinate clauses:

(8) *ê* used in, e.g., temporal subordinate clauses
kâ used in, e.g., relative clauses

The complementizer *ê* can participate in sandhi when it occurs after a vowel-final word or before a vowel-initial adverbial particle or verb stem. We will focus on a single type of case here, that where the complementizer particle merges with the final short *a* of a preceding word, apparently resulting in the deletion of the *a*.

(9) mîna + ê
êkwa mîn ê - miyo - sîhkimât
and also COMP - well - he:encouraged
'and he also encouraged them in the right way'

The complementizer *kâ* can participate in sandhi when the following adverbial particle or verb stem begins with a vowel. The cases we will focus on here involve *kâ* plus a following short *i*, which appear to coalesce into a long *ê*.

(10) kâ + isi
tânisi k - êsi - pimâcihocik
how COMP - thus - they:make:a:living

The three contexts which were measured are summarized in (11).

(11) Class 1: *ê* in a sandhi context after underlying /a/
a) transcribed as having undergone sandhi [...C ê]
b) transcribed with two separate vowels [...Ca ê]
Class 2: [kê] resulting from /kâ/ + following short /i/
Class 3: [ê] in a non-sandhi context, /C#_C/ -- control

Class 1 consists of those contexts where there is a possibility of sandhi between a final short *a* and the complementizer *ê*, as illustrated in (9). Class 1 is subdivided according to whether the transcribers felt that the potential sandhi had or had not occurred. Class 2 consists of those contexts where the complementizer *kâ* merges with a following short *i*, as illustrated in (10). Class 3 consists of control vowels, i.e., instances of the complementizer *ê* which have consonants on both sides and could not possibly have undergone sandhi.

Tokens of each of these three vowels were identified in the text. A token was used only if it did not stand at the beginning of an intonational phrase or within two syllables of the end of an intonational phrase. Tokens were only included in Class 1 if the complementizer *ê* was followed by a consonant, not another vowel.[2]

The intonational phrases containing each token were digitized at 10 000 Hz and the vowel tokens analyzed using a Kay CSL. LPC formant histories were generated for the duration of each vowel token. The formant tracks were edited manually to remove spurious formant readings and give a continuous F1 track. (In cases where the LPC algorithm gave two plausible values for F1, the value with the lower bandwidth was chosen.)

The measurements made for each vowel token were:

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[2] A possible segmental confound should be mentioned. Most Class 1 tokens occurred in the consonantal context of n_k — the most common *a*-final words undergoing sandhi being *mîna* 'also', *mâna* 'used to', and *anima* 'that one'. Most Class 3 tokens occur in the context of C#_k, where the preceding C is an obstruent.

(12) a) length of vowel
b) frequency of F1 at start of vowel
c) slope of F1

Frequency of F1 at the start of the vowel as determined by the average of the second ten frames of the formant track (that is, the LPC-estimated F1 value at each millisecond between 11 msec and 20 msec after the onset of the vowel). The overall slope of F1 was the slope of the least-mean-squares regression line fitted to the F1 track.

If external sandhi is a true phonological rule, we should expect to find the following:

(13) Predictions if sandhi is phonological
a) No length differences between Class 1a and 3
b) No differences in initial F1 between Classes 1a, 2, and 3
c) No differences in F1 slope between Classes 1a, 2, and 3

If the merger of *a* + *ê* into *ê* in Class 1 sandhi is the result of a true phonological rule that deletes the final short *a*, then the surface representation resulting from this rule will be exactly the same as one which never had an *a* in the first place (e.g., the control tokens of Class 3). The *ê* tokens of Classes 1a and 3 should be indistinguishable in terms of length, intial F1 frequency, and overall F1 slope. We have similar (though weaker) expectations for sandhi Class 2 compared to control Class 3: if a phonological rule has truly coalesced *â+i* into *ê*, then this resulting *ê* should be comparable to the control tokens of Class 3, although the differences in consonantal and syllabic context might result in slight differences.

On the other hand, if sandhi is not a phonological process, we might expect to find the following:

(14) Predictions if sandhi is not phonological
a) a longer vowel in Class 1a & 2 than in Class 3
b) a higher initial F1 in Class 1a & 2 than in Class 3
c) a (more) negative slope for F1 in Class 1a & 2

For Class 1, if no phonological rule has deleted the *a* of an *a+ê* sequence, then we would expect to see the effects of this *a* (however weakened) in the phonetic realization of the token. We would expect an *a+ê* sequence to be longer than a simple *ê* and to have a higher initial F1 value and an overall negative F1 slope as the token moves from something closer to an [a] to its final [e:]. We might also expect there to be no clear-cut distinction between those a+ee sequences which Ahenakew and Wolfart transcribed as having undergone sandhi (Class 1a) and those transcribed as not having undergone sandhi (Class 1b).

3. Results

The results of the measurements are summarized in Table 1. Boxplots for the major results are given in Figures 1-3.

	Class 1a sandhi [ê]s	Class 1b non-sandhi [a ê]s	Class 2 sandhi [kê]s	Class 3 control [ê]s
N	44	16	42	41
Length mean	0.0837	0.1008	0.0732	0.0679
s.d.	0.0499	0.0516	0.0336	0.0199
Starting F1	549.5	588.5	462.7	489.4
s.d.	67.47	83.23	62.7	58.5
Slope mean	-0.5817	-0.7671	0.0327	-0.0714
s.d.	0.4393	0.6855	0.3369	0.4821

Table 1. Results

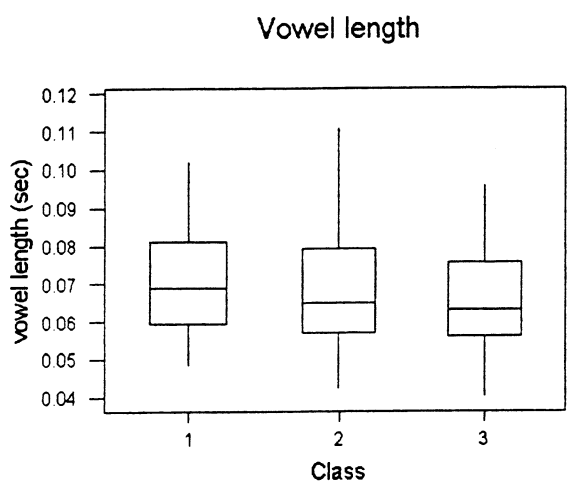

Figure 1

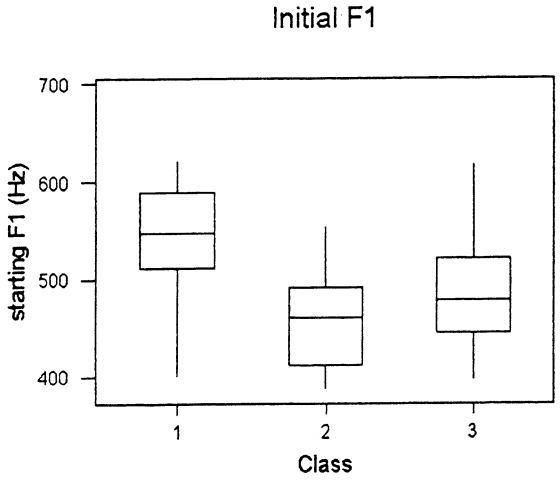

Figure 2

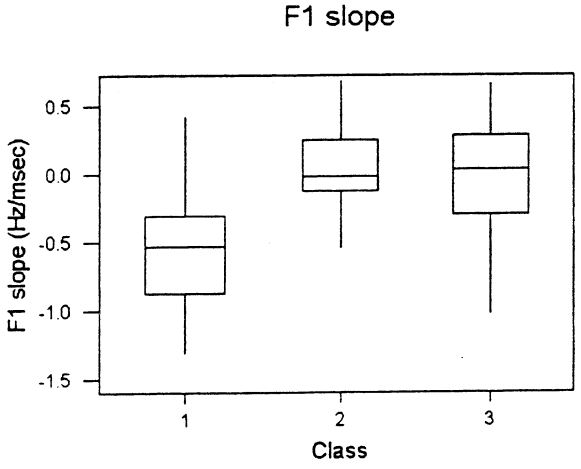

Figure 3

Comparing Class 1a against Class 3, those [e:]s which have undergone sandhi are longer than the control [e:]s (84 msec on average compared to 68 msec for the controls), but the difference is not quite significant ($F = 3.59$, $p = 0.062$). The frequency of F1 at the beginning of the vowel is significantly higher in sandhi [e:]s than in control [e:]s ($F = 19.12$, $p < 0.001$). The overall slope of F1 was significantly more negative in the sandhi [e:]s than in the control [e:]s ($F = 26.08$, $p < 0.001$).

Comparing Class 2 (kâ+i→kê) against the control class, there was no significant difference between the two in terms of either length ($F = 0.76$, $P = 0.387$) or F1 slope ($F = 1.31$, $p = 0.257$). There was a barely significant difference between the two classes in the initial frequency of F1 ($F = 3.99$, $p = 0.049$). This difference was, however, the *opposite* of the predicted difference — the initial F1 of *kê*'s resulting from *kâ+i* is *lower* than that of the control class, that is, the start of a [ke:] < /ka:+i/ is less like [a] than is an underlying [e].

4. Conclusion

Let us summarize by comparing the results just described with the expectations outlined in (13) and (14).

(17) If the underlying /a/ or /â/ has not really been deleted, we should find:
- a) a longer vowel in Class 1a (a#e) and 2 (a+i>e) than in Class 3 (control)
  - Class 1a tokens are longer than Class 3, but not quite significantly so.
  - Class 2 is not longer than Class 3.
- b) a higher initial F1 in Class 1a and 2 than in Class 3
  - Class 1a has a significantly higher initial F1 than Class 3.
  - Class 2 has a barely significantly *lower* initial F1 than Class 3.
- c) a (more) negative slope for F1 in Class 1a and 2
  - Class 1a has a significantly greater negative slope than Class 3.
  - Class 2 does not.

The conclusion we are forced to is that the final *a* in Class 1a has not really been deleted. If it had been, the resulting *ê* should have been indistinguishable from the underlying *ê* of the control class. Certainly, the word-final vowels are significantly changed from what they would be in a non-sandhi context: compare the initial F1 of 550 Hz for final [a]s in the sandhi context of Class 1a with the typical inital F1 of 686 Hz for unstressed phrase-medial word-final *a* in non-sandhi contexts. But this change cannot be attributed to a phonological deletion of the word-final /a/ segments. The articulatory target for an [a] is clearly still present and, while the articulators might seldom reach that target in a sandhi context during fluent speech, the target continues to influence the overall course of the articulators.

Things are different for Class 2, those tokens of *ê* arising from complementizer *kâ* plus a following *i*. The results suggest that these tokens truly have undergone a phonological rule which has resulted in a single [e:] target. These tokens are indistinguishable from underlying /e:/s in all respects, except for initial F1, where the [e:] resulting from /a:+i/ coalescence is even *less* like [a] than underlying /e:/s are.

This unexpected significant difference in initial F1 between Class 2 and Class 3 might be attributable to the segmental confound mentioned in footnote 2. Another possible explanation is the role of phonological contrast. Wolfart (1989) notes that the coalescence of *kâ+i* into *kê* does not seem to be truly optional. Rather, it is nearly exceptionless when the verb occurs in a realis clause, and is not found in irrealis clauses. If so, the contrast between

[ka:i] and [ke:] is semantically significant, and it is not implausible that speakers might exaggerate the difference, or rather, that speakers will take more care to approach the [e:] target in those cases where it is potentially contrastive (Class 2) than in those cases where there is no danger of confusion (Class 3).

We have a clear difference between Class 1a and Class 2 kinds of sandhi in Cree. If our ultimate goal is to do away with the need for phonological juncture rules, then Class 1a is no problem. It turns out that there is no need for a phonological rule to turn the sequence *mîna ê* into *mîn ê*. Indeed, an analysis which did make use of such a phonological rule would be empirically inferior.

But Class 2 sandhi cannot be dismissed so easily as a mere apparent quirk of phonetic interpretation. It is noteworthy, however, that Class 2 sandhi is very unlike the kind of across-the-board rules that would pose the greatest challenge for a simpler phonological theory. It was odd in the first place for being the only example of sandhi where the first vowel was long rather than short. Its application is restricted a single complementizer particle *kâ*. Its context of application is also restricted: the following short *i* will always occur in a stem or a preverb that is built on the root *it-/is-* 'thus, so'. Verbs built on this root in Cree for a class whose members share other interesting morphosyntactic properties. And, even when coalescence does occur between this single complementizer particle and this restricted class of verbs, its occurrence seems to be semantically governed and correlates with a realis modality. In short, while this coalescence is categorical, it is more comparable to the contraction of English *will not* to *won't* than to an across-the-board structure-changing sandhi phenomenon that would require a massive complication of the phonology-phonetics interface.

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