The perceptual dimensions of sonority-driven epenthesis

Michelle A. Fullwood

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Abstract

Vowel epenthesis often appears to preferentially target consonant clusters with rising sonority. One explanation for this is perceptual faithfulness (Fleischhacker, 2002; Steriade, 2006): rising sonority clusters are more susceptible to epenthesis because the perceptual distance between the underlying $/C_1C_2/$ sequence and its correspondent output sequence $[C_1VC_2]$ is small, thus incurring a smaller faithfulness cost. This raises the question of how to compute the perceptual distance between two sonority contours $/C_1C_2/$ and $[C_1VC_2]$ in terms of the sonority of C_1, C_2 and V. In this paper, I propose that the appropriate metric is SONORITY ANGLE, the angle formed by the contours C_1C_2 and C_1V, and apply it in analyzing two case studies of sonority-driven epenthesis, Chaha and Irish. A comparison is made to another possible metric, SONORITY RISE (Flemming, 2008), the ratio of the gradients of the two contours, as well as to Syllable Contact, which represents an alternative, markedness-based approach to the problem of sonority-driven epenthesis.

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1 Introduction

Vowel epenthesis often appears to preferentially target consonant clusters with rising sonority. There are two broad classes of explanation within Optimality Theory for such sonority-driven epenthesis.

One is faithfulness-based: the perceptual distance between the underlying $/C_1C_2/$ sequence and its correspondent output sequence $[C_1VC_2]$ is small when the cluster is of rising sonority. Thus, epenthesis into such a sequence incurs a smaller faithfulness cost than epenthesis into a cluster of falling sonority. This is the basis of the analysis proposed by Fleischhacker (2002, 2005) to explain why rising sonority obstruent-sonorant clusters are more easily epenthesised in to than falling sonority sibilant-stop clusters.

This faithfulness-based approach raises the question of how the perceptual distance between two sonority contours $/C_1C_2/$ and $[C_1VC_2]$ should be computed in terms of the sonority of C_1, C_2 and V.

Fleischhacker's analysis rested on empirical determinations of sonority contour faithfulness, and did not attempt to determine such a relation. Steriade (2006) proposed that input and output sonority contours should match in terms of whether they are rising or falling, and to what degree, but did not suggest a concrete mathematical relation. Flemming (2008) formalises Steriade's approach with the metric SONORITY RISE, the ratio of the gradients of the two contours.

In this paper, I suggest that any such metric should bear two properties. The first is that suggested by previous analyses, that the more positive the gradient of the sonority contour from C1 to C2, the smaller the faithfulness cost and hence the more likely epenthesis is to occur. The second is that for a given sonority distance between C1 and C2, the more sonorous C1 and C2 are, the more likely epenthesis is to occur.

To make things concrete, I suggest a metric that possesses these two properties, which I term SONORITY ANGLE. This is the magnitude of the angle made by the vectors C_1-C_2 and C_1-V. I then explore the ramifications of this choice.

SONORITY ANGLE makes the same broad predictions as SONORITY RISE — that clusters of rising sonority, having a relatively small angle between the underlying sonority contour $/C_1$-$C_2/$ and the overt sonority contour $[C_1$-V], are perceptually more similar to their epenthetic output, and therefore more likely to undergo epenthesis, than clusters of falling sonority. Crucially, however, the exact hierarchy of susceptibility of individual clusters to epenthesis is predicted to be different.

I take two instances where the predictions of SONORITY ANGLE and SONORITY RISE differ and illustrate with case studies of sonority-driven epenthesis in two different languages, namely Chaha and Irish, that the predictions of SONORITY ANGLE are more in line with the data than those of SONORITY RISE.

The other broad class of explanation for sonority-driven epenthesis is markedness-based. Syllable Contact (Murray and Vennemann, 1983) holds that across a syllable boundary, falling sonority clusters are more harmonic than rising sonority ones. Hence, rising

sonority clusters are preferentially broken up by epenthesis.

Syllable Contact forms the basis for the main existing analysis of Chaha epenthesis by Rose (2000). I show that the faithfulness-based analysis, powered by the metric of SONORITY ANGLE, is slightly more economical in addressing the data. Furthermore, in the case of Irish, Syllable Contact makes incorrect predictions regarding the data.

The layout of this paper is as follows. Section 2 lays out the theoretical background for the sonority contour faithfulness approach to sonority-driven epenthesis. I introduce the proposed SONORITY ANGLE metric as well as the competing SONORITY RISE metric (Flemming, 2008), then lay out the alternative markedness-based approach to sonority-driven epenthesis, namely SYLLABLE CONTACT.

Section 3 consists of a case study of sonority-driven epenthesis in Irish. I show that the data are in line with the predictions of SONORITY ANGLE and not SONORITY RISE, while a Syllable Contact-based analysis would have to be very complicated to explain the same facts.

Section 4 is a case study of epenthesis positioning in Chaha. I detail the facts of epenthesis positioning in Chaha, based on the data given in Rose (2000), and show that the sonority contour faithfulness approach explains these facts, with SONORITY ANGLE as the metric for comparing sonority contours. I compare it to SONORITY RISE and show that the former is the more successful analysis, and that overall, the approach just outlined is more economical than the Syllable Contact-based approach of Rose (2000).

Section 5 looks at various issues regarding SONORITY ANGLE, such as its robustness. Section 7 concludes.

2 Theoretical background

This paper assumes as its basis the P-map hypothesis (Steriade, 2001), which states that the perceptual distance between underlying representations and potential surface forms projects a fixed ranking of faithfulness constraints.

In order to determine what faithfulness constraints exist in CON and what their rankings should be, therefore, we need to know the metrics of perceptual distance that are relevant to each change. In the case of vowel epenthesis, the perceptual distance to be measured is between two sonority contours, /C1-C2/ and $[C_1\text{-}V\text{-}C_2]$.

2.1 Sonority Angle

The observation with which we started was that the more steeply rising the sonority profile of a consonant cluster, the more likely the cluster to undergo epenthesis. Thus the absolute difference in sonority between C_1 and C_2 must be factored into the metric. To this, I add the claim that the more sonorous C_1, the more likely the cluster is to undergo epenthesis.

These two factors are neatly captured by the metric SONORITY ANGLE, which is defined as the angle between the underlying C_1C_2 sonority contour and the surface C_1V contour:

(1)
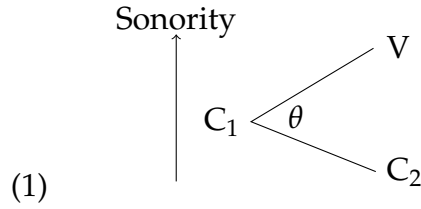
Assuming that the horizontal distance is 1 unit, we can compute the magnitude of this angle analytically with the following formula:

(2)   Formula: SONANGLE $= arctan(V - C_1) - arctan(C_2 - C_1)$

Let us verify that SONORITY ANGLE does indeed reflect the two generalisations we wish to make: first, that the smaller the sonority distance between C_1 and C_2, the smaller the sonority angle. Imagine fixing C_1 as in (1) and raising the sonority of C_2. Intuitively, this decreases the SONORITY ANGLE, comparing the two below.

(3)
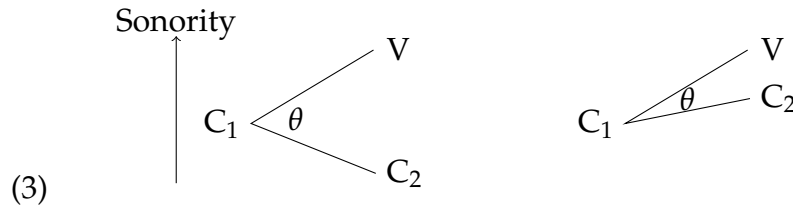
The dependence of SONORITY ANGLE on this distance can also be seen in the second term in (2).

The second generalisation is that the more sonorous the C_1, the more likely epenthesis is to occur. Let us fix the sonority distance between the two consonants of the cluster at 2, but vary their distance from V:

(4)
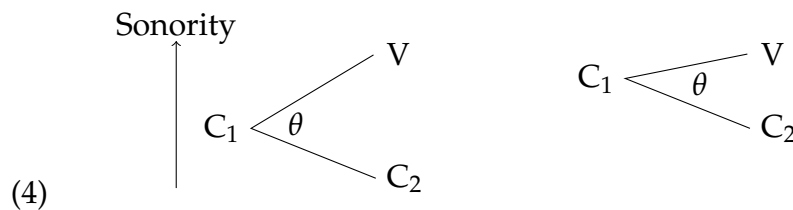
When C1 (and, by extension, C2) is of higher sonority, as on the right, the V-C1-C2 angle is clearlysmaller. The first term in the formula confirms the relation between the sonority of C_1 in terms of its closeness to V, and SONORITY ANGLE as a whole.

Given a sonority scale where classes of consonants are mapped to a numerical sonority, we can now calculate the SONORITY ANGLE for any cluster, which can be thought of as the faithfulness cost of epenthesising between the two consonants. Examples of the

calculation are given below.

In this paper, I adopt (with, later, minor modifications) the following standard scale:

	T	F	N	R	G	V
(5)	stop	fricative	nasal	liquid	glide	vowel
	1	2	3	4	5	6

The SONORITY ANGLES for NT, TT and TN are calculated as in the following examples.

(6)   a.   SONANGLE(NT) $= arctan(6-3) - arctan(1-3) = 2.35$
       b.   SONANGLE(TT) $= arctan(6-1) - arctan(1-1) = 1.37$
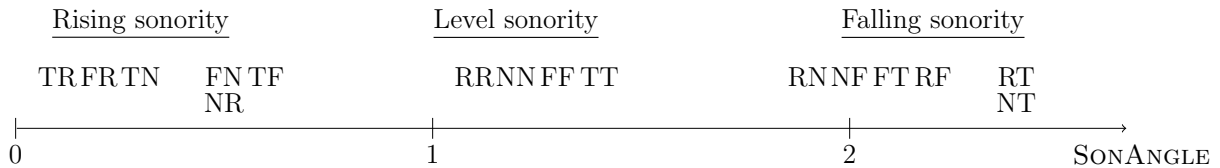   c.   SONANGLE(TN) $= arctan(6-1) - arctan(3-1) = 0.27$

The larger the SONORITY ANGLE, the larger the faithfulness cost. We therefore expect it to be hardest to epenthesise into NT out of these three clusters, and easiest to epenthesise into TN.

We formalise the idea of the faithfulness cost by defining a family of IDENT constraints that penalise outputs that incur faithfulness costs of greater than a certain n.

(7)   IDENT(SONANGLE)$< n$: Assign a violation mark if the consonants in two strings C_1C_2 and C_1VC_2 stand in correspondence, and the sonority angle between C_1C_2 and C_1V is greater than n.

This family of faithfulness constraints forms a stringency hierarchy. Any cluster that would, upon epenthesis, violate IDENT(SONANGLE)$<n$ would also violate IDENT(SONANGLE)$<m$ where m>n. The resulting hierarchy of clusters, ranked according to their resistance to epenthesis as defined by their SONORITY ANGLE, is as follows.

(8)   SONORITY ANGLE hierarchy

Rising sonority		Level sonority	Falling sonority	
TR FR TN	FN TF	RR NN FF TT	RN NF FT RF	RT
	NR			NT

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├──────────────────────┼──────────────────────┼──────────────────────►
0                      1                      2            SONANGLE
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The prediction is that when a markedness constraint targets a set of clusters for epenthesis, if a certain cluster undergoes epenthesis, then all clusters to the left of it on the hierarchy — those with a smaller SONORITY ANGLE — should also undergo epenthesis.

Notice that out of the falling sonority clusters, those that decrease in sonority by a single step – namely RN, NF and FT – have smaller SONORITY ANGLES than the ones that have a greater fall in sonority. Furthermore, out of these three clusters, the one with the most sonorous C_1, RN, has the smallest SONORITY ANGLE. We thus predict that out of the falling sonority clusters, RN is the most likely to be broken up by epenthesis. The case study on Chaha will demonstrate that this is the case.

Similarly, between the clusters that fall in sonority by two steps – RF and NT – we expect NT to be less likely to undergo epenthesis, since N is less sonorous than R. We expect NT and RT to be the clusters most resistant to epenthesis out of all the clusters. This will be crucial to our analysis of Irish sonority-driven epenthesis.

2.2 Stringency and faithfulness conflation

There are two possible ways to rank the family of IDENT(SONANGLE)<n constraints. One is to fix them in a universal ranking (Prince and Smolensky, 2003), with least stringent the highest-ranked:

(9) Universal ranking:
     IDENT(SONANGLE)<2.0 ≫ IDENT(SONANGLE)<1.5 ≫ ...

It is also possible to allow them to be freely ranked (de Lacy, 2004, and others), so that a more stringent constraint may outrank a less stringent one:

(10) Possible free ranking: IDENT(SONANGLE)<1.5 ≫ IDENT(SONANGLE)<2.0 ≫ ...

Depending on what constraints intervene, this may result in conflation of certain areas of the hierarchy, so that any distinctions between SONORITY ANGLES between 1.5 and 2.0 may be conflated.

In this paper, for ease of analysis, I will assume that all IDENT(SONANGLE)<n constraints are ranked low by default, but that individual IDENT(SONANGLE)<n constraints can be promoted to dominate a markedness constraint $\mathcal{M}$ against clusters or another faithfulness constraint $\mathcal{F}$, blocking epenthesis for all clusters with a SONORITY ANGLE greater than n, with the result that either the cluster remains intact, or a competing solution to epenthesis emerges.

An example of IDENT(SONANGLE)<n blocking epenthesis is given in the sample tableaux below.

(11) Ident(SonAngle)<1.5 ≫ *COMPLEXCODA ≫ DEP
     a. Allows epenthesis in rising and level clusters such as stop-fricative TF:

Input: /TF/	IDENT(SONANGLE)<1.5	*COMPLEXCODA	DEP
a. TF		*!	
b. ☞ TəF	0.59		*

     b. Prevents epenthesis in falling clusters such as FT:

7

Input: /FT/	IDENT(SONANGLE)<1.5	*COMPLEXCODA	DEP
c. ☞ FT		*	
d. FəT	2.11 *!		*

We will see more examples of this in the analysis of Irish epenthesis as well as Chaha coda cluster epenthesis.

I will illustrate the use of IDENT(SONANGLE)<n to block epenthesis in favour of other cluster resolution strategies with an example from the loanword phonology of the Dhaka dialect of Bangla, discussed and analysed in (Karim, 2011). Standard Bangla keeps coda clusters in words borrowed from English, but these are simplified in the Dhaka dialect in a variety of ways, including both epenthesis and deletion of one of the consonants in the cluster.

(12) a. RN clusters are broken up via copy epenthesis
   (i) hɔrn → hɔrɔn 'horn'
   (ii) pʰɔrm → pʰɔrɔm 'form'
   (iii) fɪlm → fɪlɪm 'film'
 b. RT clusters resolved by deletion of [r]
   (i) park → pak 'park'
   (ii) ʈɔrc → ʈɔc 'torch'
   (iii) narbʰ → nabʰ 'nerve'
   (Karim, 2011, (4,5))

From the examples in (12-a), we see that MAX(r) ≫ DEP in general, making epenthesis the preferred way of dealing with the cluster.

(13) *COMPLEXCODA ≫ MAX(r) ≫ DEP

Input: /hɔrn/	*COMPLEXCODA	MAX(r)	DEP
a. hɔrn	*!		
b. ☞ hɔrɔn			*
c. hɔn		*!	

However, if we retain this ranking, we incorrectly expect RT clusters to be broken up by epenthesis rather than delete the [r]. This can be resolved by ranking IDENT(SONANGLE)<2.3, say, above MAX(r). This then blocks epenthesis in RT clusters, which have a SONORITY ANGLE of 2.35:

(14) *COMPLEXCODA, IDENT(SONANGLE)<2.3 ≫ MAX(r) ≫ DEP

Input: /park/	*COMPLEXCODA	IDENT(SONANGLE)<2.3	MAX(r)	DEP
a.　　　park	*!			
b.　　　parak		*!		*
c.　☞　pak			*	

Since RN clusters have a smaller SONORITY ANGLE of 1.9, their behaviour does not change with this ranking.

While other analyses could possibly account for this data (see one such in (Karim, 2011)), we see that simply ranking IDENT(SONANGLE)<n $\gg \mathcal{F}$ allows us to account for it quite straightforwardly.

Thus far, we have not made any particular use of free ranking. While ranking IDENT(SONANGLE)<r $\gg \mathcal{M}$ does conflate all clusters with a SONORITY ANGLE above n, as well as all clusters with a SONORITY ANGLE below n, preserving only the distinction between SONORITY ANGLES greater and less than n, this could be accomplished using a universal ranking of the IDENT(SONANGLE)<n constraints as well, as illustrated in the following example:

(15)　　The IDENT(SONANGLE)<n with the smallest n that outranks *COMPLEXCODA determines the cut-off point.

Input: /TF/	ID(SA)<2.0	ID(SA)<1.5	*COMPCODA	ID(SA)<1.0	ID(SA)<0.5
a.　　　TF			*!		
b.　☞　TəF	0.59	0.59		0.59	0.59 *

Input: /FT/	ID(SA)<2.5	ID(SA)<1.5	*COMPCODA	ID(SA)<1.0	ID(SA)<0.5
c.　☞　FT			*		
d.　　　FəT	2.11	2.11 *!		2.11 *	2.11 *

Where free ranking comes into play is when two output candidates break up different clusters. We will see examples of this in the analysis of Chaha three- and four-consonant clusters. I will give a schematic example here to illustrate the phenomenon.

Suppose a triconsonantal cluster /CCC/ has to be broken up either as [CəCC] or [CCəC], and further that [CəCC] violates some additional markedness constraint $\mathcal{M}$. Which IDENT(SONANGLE)<n constraint outranks $\mathcal{M}$ will then determine the positioning of the epenthetic vowel.

(16)　　IDENT(SONANGLE)<n $\gg \mathcal{M}$

　　　a.　Scenario 1: SONANGLE(C1-C2), SONANGLE(C2,C3)<n
　　　　　Since neither violates IDENT(SONANGLE)<n, $\mathcal{M}$ determines output.

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Input: /C1C2C3/	IDENT(SONANGLE)<n	$\mathcal{M}$
a. ☞ C1C2əC3	<n	
b. C1əC2C3	<n	*!

    b. Scenario 2: SONANGLE(C1-C2)>n, SONANGLE(C2,C3)<n
       C1əC2C3 harmonically bound by C1C2əC3 candidate.

Input: /C1C2C3/	IDENT(SONANGLE)<n	$\mathcal{M}$
c. ☞ C1C2əC3	<n	
d. C1əC2C3	>n *!	*

    c. Scenario 3: SONANGLE(C1-C2)<n, SONANGLE(C2,C3)>n
       IDENT(SONANGLE)<n determines output, overruling $\mathcal{M}$.

Input: /C1C2C3/	IDENT(SONANGLE)<n	$\mathcal{M}$
e. C1C2əC3	>n *!	
f. ☞ C1əC2C3	>n	*

    d. Scenario 4: SONANGLE(C1-C2), SONANGLE(C2-C3) > n
       Since both candidates violate IDENT(SONANGLE)<n, $\mathcal{M}$ determines output.

Input: /C1C2C3/	IDENT(SONANGLE)<n	$\mathcal{M}$
g. C1C2əC3	>n *	
h. ☞ C1əC2C3	>n *	*

Because we have assumed that all other IDENT(SONANGLE)<n constraints rank low, certainly below $\mathcal{M}$, the degree to which candidates (g) and (h) violate IDENT(SONANGLE)<n is irrelevant — the distinction between clusters with SONORITY ANGLES above n has been conflated. Even if SONORITY ANGLE(C2,C3) exceeds SONORITY ANGLE(C1,C2), the outcome is determined by the markedness constraint $\mathcal{M}$.

    Contrast this with the universal ranking, under which this distinction would be relevant. Numbers are given for clarity.

(17)   Scenario: SONANGLE(C2-C3) > SONANGLE(C1-C2) > n

Input: /C1C2C3/	IDENT(SONANGLE)<1.9	IDENT(SONANGLE)<1.5	$\mathcal{M}$
a. ☞ C1C2əC3	2.0 *!	2.0 *	
b. C1əC2C3	1.7	1.7 *	*

    Under a universal ranking of IDENT(SONANGLE)<n constraints, [C1C2əC3] would win in this scenario. In an equivalent scenario under free-ranking, where IDENT(SONANGLE)<1.5

is the least stringent constraint to outrank $\mathcal{M}$, which in turn outranks all more stringent IDENT(SONANGLE)<n constraints, the [C1C2əC3] candidate would win instead. There would be conflation of all clusters with SONORITY ANGLES below n, but distinctions between clusters with SONORITY ANGLES would still be relevant.

The example of Chaha will show that free-ranking is necessary, as conflation is observed on both sides of n, where IDENT(SONANGLE)<n is the most stringent constraint to outrank $\mathcal{M}$.

2.3 Sonority Rise

I now turn to an alternative metric of sonority contour faithfulness proposed by Flemming (2008), SONORITY RISE, which takes the ratio of the underlying sonority contour $/C_1C_2/$ and the surface contour $[C_1V]$ and subtracts that from 1.

(18)   SONORITY RISE $= 1 - \frac{C_2 - C_1}{V - C_1}$

The following sample calculations illustrate how SONRISE distance is computed:

(19)

C_1C_2	Rise	C_1V	Rise	SONRISE Distance
NT	-2	NɨT	3	$1 - \frac{1-3}{6-3} = 1.7$
TT	0	TɨT	5	$1 - \frac{1-1}{6-1} = 1.0$
TN	2	TɨN	5	$1 - \frac{3-1}{6-1} = 0.6$

As with SONORITY ANGLE, this gives rise to a family of constraints IDENT(SONRISE)$< n$, defined similarly to IDENT(SONANGLE)<n.

SONORITY RISE also gives rise to a hierarchy of susceptibility of clusters.

(20)   SONORITY RISE hierarchy
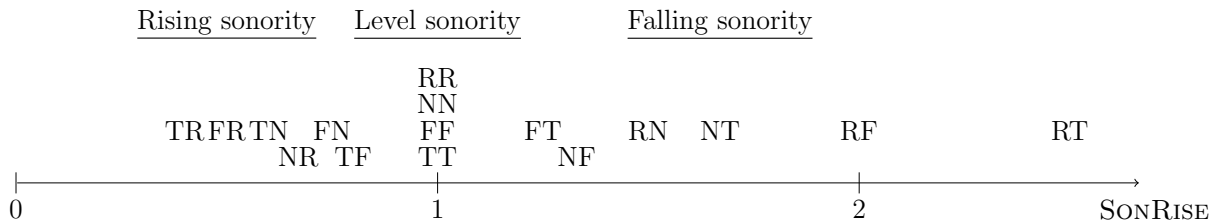
Observe that of the two desiderata for such a metric, SONORITY RISE fulfills the first but not the second. Consider the falling sonority clusters. RN, NF and FT, which all have a sonority distance of -1, have a smaller SONORITY RISE than NT and RF, with a sonority distance of 2, followed by RT with a sonority distance of 3.

However, of the three, RN has the largest SONORITY RISE, and therefore is expected to be more resistant to epenthesis than NF and FT. If RN undergoes epenthesis, therefore, we predict FT and NF to do the same.

Another prediction is that if NT and RT fail to undergo epenthesis due to the high faithfulness cost of interrupting these clusters, then RF should also fail to undergo epenthesis. Both of these predictions are contrary to the evidence of Irish and Chaha.

2.4   Another dimension of sonority contour faithfulness

Note that I do not claim that sonority contour faithfulness is the only dimension of perceptual similarity relevant to vowel epenthesis. For instance, I will adopt Flemming (2008)'s suggestion that a further dimension of perceptual similarity restricts epenthesis to sites adjacent to a sonorant, based on patterns of epenthesis in languages such as Montana Salish, where epenthesis is disallowed between two obstruents.

I will formalise this restriction with the constraint DEP(+SONORANT). The epenthesis of a vowel between two obstruents, which bear the feature [−sonorant], necessitates the insertion of a new [+sonorant] feature, whereas when a vowel is epenthesised adjacent to a sonorant, the sonorant's [+sonorant] feature spreads and is shared between the vowel and the sonorant.

This constraint will be used in the analysis of Chaha complex coda epenthesis, which in some idiolects cannot occur between obstruents, while in others, it can. My proposal will be that in the former, DEP(+SONORANT) is higher-ranked, thus blocking epenthesis.

2.5   Syllable Contact

The alternative markedness-based approach to sonority-driven epenthesis that I will explore in this paper is Syllable Contact, which was first stated as the Syllable Contact Law by Murray and Vennemann (1983):

(21)   "The preference for a syllabic structure *A$B*, where *A* and *B* are marginal segments and *a* and *b* are the Consonantal Strength values of *A* and *B* respectively, increases with the value of *b* minus *a*" (Murray and Vennemann, 1983)

Rose (2000) reformulates this as a violable, but categorical, constraint within the context of Optimality Theory and uses it in an analysis of Chaha sonority-driven epenthesis:

(22)   SYLLCON: The first segment of the onset of a syllable must be lower in sonority than the last segment in the immediately preceding syllable.

More recently, Syllable Contact has been recast as a gradient family of constraints, for example by Gouskova (2002, 2004). She defines the distance DIS between two consonants in a syllable contact situation as the sonority of the second minus the sonority of the first. For example, [t.s] = +1 if [s] and [t] are only one step apart on a sonority scale. She then defines the following family of constraints:

(23)   *DIS-*n*: Assign a violation mark if the DIS between two adjacent heterosyllabic consonants is *n* (adapted from (Gouskova, 2002))

This gives rise to a universal hierarchy:

(24) *DIS+7 ≫ *DIS+6 ≫ ... *DIS+0 ≫ *DIS-1 ≫ ... *DIS-7.

Thus heterosyllabic clusters that rise sharply in sonority – that have a high DIS – are more marked than more falling clusters.

The predicted hierarchy of susceptibility to epenthesis of the clusters is as follows:

(25) Syllable Contact hierarchy (based on *DIS):

			Rising sonority		Level sonority			Falling sonority	
					RR	RN		RF	RT
			NR		NN	NF		NT	
		FR	FN		FF	FT			
	TR	TN	TF		TT				
	-3	-2	-1		0	1		2	3 DIS
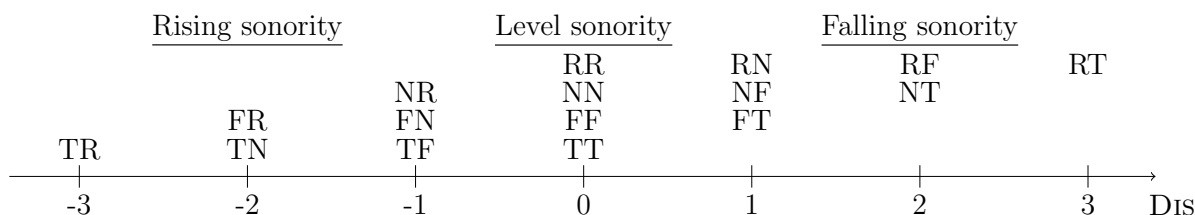
Syllable Contact applies only across syllable boundaries. Therefore, when sonority-driven epenthesis occurs in onsets or codas, other sonority-based markedness constraints must be employed. One such is SONORITY SEQUENCING (Selkirk, 1984), which states that sonority must be strictly increasing in the onset and strictly decreasing in the coda. (Rose, 2000) uses two variants of this constraint, one strict and one non-strict, in her analysis of Chaha.

3 Case study: Irish

Irish displays an unusual process of epenthesis that targets consonant clusters whose first member is a sonorant (Carnie, 1994; Ní Chiosáin, 1999), with the exception of sonorant-voiceless stop clusters, which never undergo epenthesis. I will show in this section that a SONORITY ANGLE-based faithfulness neatly captures these facts.

3.1 Data

Irish epenthesis targets sonorant-initial clusters and occurs both across syllable boundaries and in codas. The epenthetic vowel is [ə] in nonpalatalised environments and [i] otherwise (Ní Chiosáin, 1999).

(26) a. /albə/ → [aləbə]
         Alba 'Scotland'
     b. /dorxə/ → [dorəxə]
         dorcha 'dark'
     c. /gorm/ → [gorəm]
         gorm 'blue'

    d.   /banbə/ → [banəbə]
        Banba 'a name for Ireland'
    e.   /konfə/ → [konəfə]
        confadh 'anger'
    f.   /anʲmʲ/ → [anʲimʲ]
        ainm 'name'
    (Carnie, 1994, (37)) and (Ní Chiosáin, 1999, (2))

The pattern of epenthesis outlined above does not apply to onset clusters. Sonorant-initial clusters are attested in onsets.

(27)   a.   [mnaː] or [mraː] (depending on dialect)
          mná 'women'
      b.   [mʲrʲiːraːn]
          mriathán 'sea-rods'
      (Swingle, 1992, 456)

There are two classes of exceptions to this process. First, homorganic clusters are not broken up by epenthesis.

(28)   a.   /farnoːg/ → [farnoːg], *[farənoːg]
          fearnog 'alder'
      b.   /bord/ → [bord], *[borəd]
          bord 'table'
      c.   /kalrə/ → [kalrə], *[kalərə]
          calra 'calorie'
      (Carnie, 1994, (52))[1]

Second, epenthesis does not apply when the second consonant is a voiceless stop.

(29)   a.   /kork/ → [kork], *[korək]
          Cork 'Cork (place name)'
      b.   /korkə/ → [korkə], *[korəkə]
          corca 'people'
      c.   /korp/ → [korp], *[korəp]
          corp 'body'
      d.   /baŋk/ → [baŋk], *[baŋək]
          banc 'bank'
      (Carnie, 1994, (39a,b,c,26c))

---

[1]Ní Chiosáin (1999) has a more complicated set of facts as to which homorganic clusters are broken up by epenthesis. As this is not the focus of this paper, I will assume the simpler dataset that Carnie presents.

3.2 Analysis

The fact that this process of epenthesis does not target obstruent-initial clusters is not problematic under the sonority contour faithfulness approach, as the IDENT(SONANGLE) constraints limit epenthesis, rather than trigger it. By choosing a more limited markedness constraint such as *SON-C, defined below, we can have epenthesis act only on sonorant-initial clusters.

(30) *SON-C: Assign a violation mark for every sonorant consonant preceding another consonant.

(31) *SON-C ≫ DEP

Input: /ɡorm/	*SON-C	DEP
a. ☞ ɡorəm		*
b. ɡorm	*!	

Epenthesis does not break up onset sonorant-initial clusters. This is likely due to the fact that with a small number of lexical exceptions, Irish words are stress-initial (Ó Siadhail, 1989, 26).[2] Breaking up the onset cluster would result in an unstressable epenthetic vowel occupying the preferred location of stress in Irish.

I will assume initial stress is due to the following constraint, which is dominated only by lexicon-specific constraints.

(32) STRESS-INITIAL: Assign a violation mark if the initial syllable of a word is not stressed.

Alderete (2000) proposes a general constraint HEAD-DEPENDENCE against making an epenthetic segment a prosodic head, which I adopt and state informally here:

(33) HEAD-DEP: Assign a violation mark for every stressed vowel not present in the input.

Together, these two constraints ranking above *SON-C predict that onset epenthesis does not occur.

(34) STRESS-INITIAL, HEAD-DEP ≫ *SON-C

Input: /mnaː/	STRESS-INITIAL	HEAD-DEP	*SON-C
a. ☞ ˈmnaː			*
b. ˈmə.naː		*!	
c. mə.ˈnaː	*!		

---

[2] With the exception of Munster Irish, where stress is attracted to syllables containing a long vowel or diphthong (Green, 1996), but where onset clusters still are not broken up by epenthesis. In this case, one would probably have to posit a positional faithfulness constraint protecting the word-initial cluster.

In codas and across syllable boundaries, epenthesis does not apply to homorganic clusters. I suggest that this is due to the action of the Obligatory Contour Principle (OCP). I adopt Walters (2007)'s formulation of the OCP, which bans successive identical oral gestures. A cluster such as [nd] would consist of a single oral constriction gesture at the alveolar ridge, and would not constitute a violation of the OCP. Splitting it by epenthesis to form [nəd] would require a repeated identical constriction gesture, and therefore be a violation of the OCP.

(35)   OCP ≫ *SON-C

Input: /bord/	OCP	*SON-C
a. ☞ bord		*
b. borəd	*!	

Lastly, we come to the sonority-driven aspect of the analysis. Epenthesis is allowed when C1 is "followed by a voiced stop, fricative, nasal or liquid, but not when it is followed by a voiceless stop." (Carnie, 1994)

This requires a revision to the standard sonority scale, splitting up voiceless and voiced stops:

	Voiceless stop	Voiced stop	Fricative	Nasal	Liquid	Glide	Vowel
(36)	T	D	F	N	R	G	V
	1	1.5	2	3	4	5	6

Now let us calculate the sonority angles for the relevant set of sonorant-initial clusters in Irish.

(37)   SONORITY ANGLES of sonorant-initial clusters using revised sonority scale

The sonorant-voiceless stop clusters can be neatly separated from the rest of the clusters in terms of SONORITY ANGLE. The correct constraint ranking is therefore the following:

(38)   IDENT(SONANGLE)<2.3 ≫ *SON-C ≫ IDENT(SONANGLE)<2.4

Input: /kork/	IDENT(SONANGLE)<2.3	*SON-C	IDENT(SONANGLE)<2.4
a. ☞ kork		*	
b. korək	2.35 *!		2.35 *

Input: /albə/	IDENT(SONANGLE)<2.3	*SON-C	IDENT(SONANGLE)<2.4
c. ☞ alәbә	2.29		2.29
d. albә		*!	

A note on the nasal-voiceless stop clusters is in order here: such clusters tend to be homorganic on the surface. It is therefore unclear whether such clusters failed to be broken up by epenthesis because of OCP, or because of the large sonority contour faithfulness violation. I argue that in general, it is for the second reason.

Suppose nasal-voiceless stop clusters were banned from epenthesising because of the OCP. Then we would expect to see surface sequences of [NVP] where N and P have different places of articulation and V is an epenthetic vowel, just as we see [NVB] sequences:

(39) a. [bʲinʲib]
          binb 'venom'
      b. [banәbә]
          Banba 'Banba (a name for Ireland)'
          (Carnie, 1994, 2c)

To my knowledge, no [NVP] sequences with the properties stated above exist.

Further, albeit marginal, evidence comes from the existence of words with heterorganic [NP] sequences, which are not broken up by epenthesis.

(40) a. [sʲeːmt]
          séimt 'the act of playing music', dialectal variant of *seinm*)
      b. [kʌrʲəmʲkʲ]
          cuirimc 'I observe, pay attention to' (Connaught dialect)
          (Words found in Dineen (1927))

I conclude that in general, epenthesis does not occur in /NT/ sequences due to the large SONORITY ANGLE between NT and NVT, and not to the non-existence of underlying heterorganic /NP/ clusters in the lexicon. The epenthetic facts of Irish thus support the ranking of NT and RT clusters at the bottom of the hierarchy of susceptibility to epenthesis, which is consistent with the SONORITY ANGLE metric.

3.3   Comparison to other approaches

Using the same revised sonority scale, the SONORITY RISE calculations are as follows for the relevant clusters:

(41)   SONORITY RISES of sonorant-initial clusters using revised sonority scale

		RR		RN				
NR		NN	NF	ND	NT	RF	RD	RT

→
SONORITY RISE

Note that the clusters RF and RD fall between RT and NT on this scale. Therefore, we cannot clearly separate the clusters that undergo epenthesis from the ones that do not if we adopt SONORITY RISE as the relevant metric.

Carnie's (1994) analysis of these facts is in terms of a Minimal Distancing Constraint with various parameter settings, such as for which direction away from the nucleus it applies (to the right in the Irish case, to account for epenthesis applying to both codas and heterosyllabic clusters). His preliminary analysis has distance computed according to the following sonority scale:

(42) a. 1 - Voiceless stops
   b. 2 - Voiced stops
   c. 3 - Voiceless fricatives
   d. 4 - Voiced fricatives
   e. 5 - Sonorants

with a subsequent revision where sonority is computed in terms of the number of nodes that have to be specified to obtain the appropriate manner specification. This computation is somewhat complicated, so I will not reproduce it here. The result is that sonorant-fricative and sonorant-voiced stop clusters have a sonority distance of 0, since they are each specified for a single node in the feature geometry. Voiceless stops have no specified nodes, so sonorant-voiceless stop clusters have a sonority distance of 1, which is the minimal distance tolerated.

A sonority scale that gives nasals and liquids identical sonority values seems unlikely given measurable differences in the phonetic correlates of sonority such as intensity between liquids and nasals (Parker, 2002). This is especially so when the obstruents are spread so widely on the sonority scale. I will therefore explore instead an alternative sonority distance-based analysis using Syllable Contact.

We quickly see that Syllable Contact on its own is insufficient as epenthesis in Irish also affects coda clusters. We will need to invoke Sonority Sequencing.

Attempting to apply Syllable Contact to the Irish case, we immediately encounter problems. Firstly, it is difficult to see why markedness triggers epenthesis only in sonorant-initial clusters, as Syllable Contact predicts that obstruent-initial clusters should be even more marked.

Secondly, we would need to invoke a separate set of constraints on sonority sequencing in coda clusters, and assume that the ranking of the faithfulness constraint DEP with respect to both sets of constraints is coincidentally identical.

Suppose we define a single markedness constraint that favours all falling sonority clusters regardless of their position in the syllable, i.e. combining Syllable Contact and Sonority Sequencing. We require a finer-grained metric to measure how marked a particular cluster is. An obvious course of action is to use Gouskova (2002)'s *Dɪs metric, extending its use from the heterosyllabic environment alone to all positions.

Using the defined sonority scale, we expect the following markedness hierarchy of sonorant-initial clusters.

$$
\begin{array}{ccccccc}
 & \text{RR} & \text{RN} & & \text{RF} & & \\
\text{NR} & \text{NN} & \text{NF} & \text{ND} & \text{NT} & \text{RD} & \text{RT}
\end{array}
$$

$$\xrightarrow{\hspace{10cm}} \text{Dɪs}$$
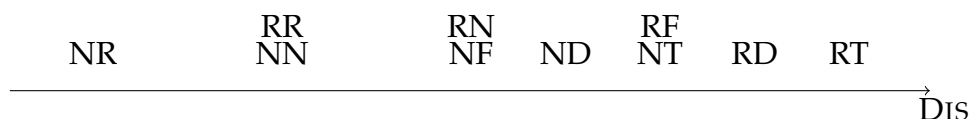
Even ignoring the problem of the obstruent-initial clusters, we see that sonority distance alone does not get us the desired result. Instead, it incorrectly predicts that if NT and RT are not broken up by epenthesis, then RF and RD should not either.

3.4   Interim summary

To summarise the findings of the Irish case study: a sonority contour faithfulness account explains the facts quite simply, because Sᴏɴᴏʀɪᴛʏ Aɴɢʟᴇ successfully achieves a linear separation of the NT and RT clusters from the remaining sonorant-initial clusters, explaining why they fail to undergo epenthesis. The Sᴏɴᴏʀɪᴛʏ Rɪsᴇ metric does not have the same property. We have also seen that a markedness-based account would have to be much more complicated to explain the same facts.

4   Case study: Chaha

Chaha is a Southern Semitic language spoken in central Ethiopia by about 440,000 people. As is common with Semitic languages, it has many underlying consonant clusters, some of which are resolved by epenthesis of the high central vowel [ɨ]. Vowel epenthesis appears to preferentially target rising and level sonority clusters over falling ones. The data in this section mostly comes from Rose 2000, who also provides an analysis in terms of Syllable Contact.

We will use the existing sonority scale given in (5), with a small modification. Chaha has a bilabial approximant represented by [β] (more precisely, β̞) (Banksira, 2000, 15) that is not as sonorous as /r/, whose realisation is tap-like (Taranto, 2001, 181). The justification for /β/ being less sonorous than /r/ is largely empirical, based on the epenthetic behaviour of clusters containing this sonorant (Rose, 2000, 405), data for which will be presented later in this paper. I will specify its sonority as an intermediate 3.5, under the sonority of 4 for liquids in general.

(43)   Sonority scale to be used in Chaha

V	>	w j	>	r	>	β	>	m n	>	f s z x	>	t t′ k k′ d g
vowels		glides		liquids				nasals		fricatives		stops
V		G		R		β		N		F		T
6		5		4		3.5		3		2		1

4.1 CC clusters

4.1.1 Data

Underlying two-consonant clusters in Chaha are obligatorily epenthesised into if initial, never broken up by epenthesis in medial position, while final clusters are epenthesised into if they are of rising or level sonority, or the cluster consists of [r] followed by a nasal.

(44) No onset clusters in Chaha

   a. kɨrətam 'he lifted up' (Rose, 2000, 398)

(45) Tautomorphemic medial two-consonant clusters are tolerated no matter what their sonority profile

   a. sɨrto 'cauterise (MASC PL)!'
   b. nɨk'mo 'pick (MASC PL)!'
   c. at'met' 'solidified juice from [əsət] plant'

   (Rose, 2000, (1a,c,d))

The presentation of the patterns of epenthesis in CC# clusters is slightly complicated by variability between idiolects. Epenthesis is possible in all level and rising sonority clusters. Among these clusters, the ones for which epenthesis is optionally unavailable are the obstruent-obstruent clusters. Most falling sonority clusters do not undergo epenthesis, except [r]-sonorant clusters, which can be broken up in certain idiolects. Voicing is irrelevant to whether clusters undergo epenthesis.

The following table summarises the data.

(46) Table showing epenthesis patterns for clusters of varying sonority patterns:

C1 \ C2	Stop	Fricative	Nasal	Liquid
Stop	**OPTIONAL** nɨg(ɨ)d 'touch!'	**OPTIONAL** dɨg(ɨ)s 'give feast!'	✓ nɨkɨm 'pick!'	✓ gɨdɨr 'put to bed!'
Fric-ative	✗ kɨft 'open!'	**OPTIONAL** mes(ɨ)x 'chew!'	✓	✓ sɨfɨr 'measure!'
Nasal	✗ gɨnd 'log (noun)'	✗ tɨmx 'scoop with finger!'	✓ gənɨm 'take back loaned cow!'	✓
Liquid	✗ fɨrt 'divide in half!'	✗ tɨrx 'make incision!'	**OPTIONAL** kɨr(ɨ)m 'insult!'	✓ sɨβɨr 'break!'

(Data assembled from Rose (2000, 404–7))

The variability therefore lies in (1) whether epenthesis between obstruents is possible (between stops, between a stop and a fricative, and between two fricatives), and (2) whether [r]-sonorant can be broken up by epenthesis or not.

The variable setting of these two options corresponds to four attested idiolects:

(47)　　The four idiolects: (Rose, 2000, (43))

　　　　a.　✓OVO, ✗rVN
　　　　　　[kɨrm], [sɨβɨr], [kɨft], [kɨtɨf], [sɨgɨd]
　　　　b.　✓OVO, ✓rVN
　　　　　　[kɨrɨm], [sɨβɨr], [kɨft], [kɨtɨf], [sɨgɨd]
　　　　c.　✗OVO, ✗rVN
　　　　　　[kɨrm], [sɨβɨr], [kɨft], [kɨtf], [sɨgd]
　　　　d.　✗OVO, ✓rVN
　　　　　　[kɨrɨm], [sɨβɨr], [kɨft], [kɨtf], [sɨgd]

4.1.2　Analysis

Under a sonority contour faithfulness analysis, epenthesis is triggered by a markedness constraint on the structural conditions of the cluster, not by the markedness of the underlying sonority contour profile itself. Undominated *COMPLEXONSET accounts for the non-existence of initial clusters. *CODA is ranked low, and therefore medial clusters are left intact.*COMPLEXCODA, dominated by an IDENT(SONANGLE) constraint, explains why some coda clusters are broken up by epenthesis while others are not.

In idiolect (47-a), all coda clusters of rising and level sonority – that is, those with a SONORITY ANGLE smaller than 1.5 – are broken up by epenthesis, while falling sonority clusters – those with a SONORITY ANGLE greater than 1.5 – are left intact.

(48) All clusters with a SONORITY ANGLE to the left of the dividing line undergo epenthesis while those to the right resist it, with one exception.

Rising sonority		Level sonority		Falling sonority

```
        TN                          FF                              RF    βT
  TR FR  Fβ  NR  TF      Nβ    RR  NN  TT  ┊ Rβ      RN  NF  bF     RT
     Tβ          FN   βR         ββ        ┊     βN          FT     NT
  ├────────────────────┼──────────────┼───────────┼─────────────────────→
  0                    1            1.5          2              SONANGLE
```
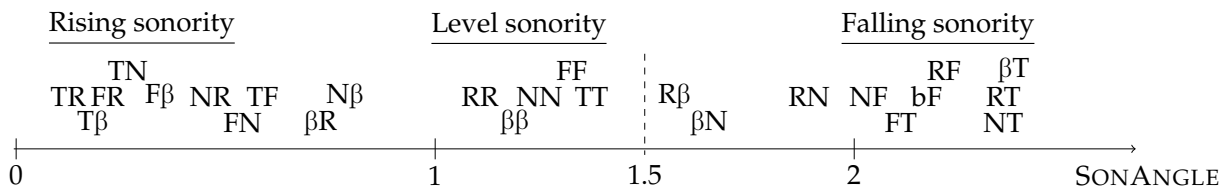
The constraint ranking for this idiolect is thus:

(49)   IDENT(SONANGLE)<1.5 ≫ *COMPLEXCODA

Input: /kɨtf/	IDENT(SONANGLE)<1.5	*COMPLEXCODA
a. kɨtf		*!
b. ☞ kɨtɨf	0.59	

Input: /kɨrm/	IDENT(SONANGLE)<1.5	*COMPLEXCODA
c. ☞ kɨrm		*
d. kɨrɨm	1.89 *!	

This approach does make one incorrect prediction: it predicts that /βm/ should not undergo epenthesis under this ranking, since /βN/ has a SONORITY ANGLE of 1.65. But it always does:

(50)   /səβ-m/ → səβim 'people-EMPH' (Rose, 2000, fn. 16)

The only clusters that give us evidence of this are /βm/ clusters. These are not seen root-internally due to a high-ranking OCP effect (Greenberg, 1950, cited in (Rose, 2000)). I suggest that there might be an undominated markedness constraint against this cluster – either OCP(labial) or another constraint based on articulatory or perceptual difficulty – that outranks all relevant faithfulness constraints.

Proceeding to idiolect (47-b), we find that [r]-sonorant clusters are allowed word-finally. Because SONORITY ANGLE permits a linear separation of the [r]-sonorant clusters from the remainder of the falling sonority clusters, this is straightforward to explain by the movement of the cut-off line from 1.5 to 1.9.

Rising sonority		Level sonority		Falling sonority

```
        TN                          FF                              RF    βT
  TR FR  Fβ  NR  TF      Nβ    RR  NN  TT   Rβ      RN ┊ NF  bF     RT
     Tβ          FN   βR         ββ              βN   ┊       FT     NT
  ├────────────────────┼──────────────────────────┼───┼─────────────────→
  0                    1                         1.9  2          SONANGLE
```
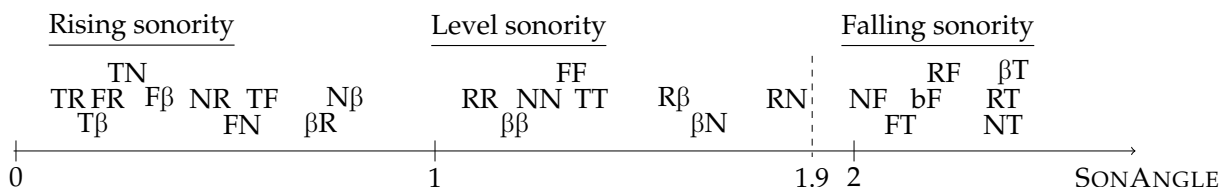
(51)   IDENT(SONANGLE)<1.9 ≫ *COMPLEXCODA

Input: /kɨrm/	IDENT(SONANGLE)<1.9	*COMPLEXCODA
a. kɨrm		*!
b. ☞ kɨrɨm	1.89	

Idiolects (47-c) and (47-d) are identical to (47-a) and (47-b) respectively, except that obstruent-obstruent clusters do not undergo epenthesis under any circumstances. This can be achieved by ranking DEP(+son) above *COMPLEXCODA.

(52)   Ranking for idiolect (47-c)

Input: /sɨgd/	DEP(+son)	IDENT(SONANGLE)<1.5	*COMPLEXCODA
a. ☞ sɨgd			*
b. sɨgɨd	*!	1.37	

To summarise, coda epenthesis behaviour in Chaha can be explained by the ranking of a IDENT(SONANGLE)<n constraint above the markedness constraint triggering epenthesis, *COMPLEXCODA. The evidence of the epenthetic behaviour of Chaha coda clusters accords with the SONORITY ANGLE prediction that RN should be the most likely to epenthesise out of the falling sonority clusters. It also demonstrates the action of a faithfulness constraint against introducing a sonorant region between two obstruents, DEP(+son), as defined in §2.4.

(53)   Rankings for the four idiolects:
   a.   IDENT(SONANGLE)<1.5 ≫ *COMPLEXCODA ≫ DEP(+son)
   b.   IDENT(SONANGLE)<1.9 ≫ *COMPLEXCODA ≫ DEP(+son)
   c.   IDENT(SONANGLE)<1.5, DEP(+son) ≫ *COMPLEXCODA
   d.   IDENT(SONANGLE)<1.9, DEP(+son) ≫ *COMPLEXCODA

4.1.3   Comparison to other approaches

SONORITY RISE can explain idiolects (47-a) and (47-c), where the cut-off is drawn between rising and level sonority clusters on the one hand and falling sonority clusters on the other, it is less straightforward to explain the behaviour of idiolects (47-b) and (47-d). This is because the cluster hierarchy predicted by SONORITY RISE does not permit a linear separation of [r]-sonorant clusters from the other falling sonority clusters: if RN undergoes epenthesis, we expect that FT and NF should also, but FT never does.

```
 Rising sonority    Level sonority          Falling sonority
                       RR
                       NN
         TR FR TN   FN  FF      FT     RN    NT         RF                RT
             NR  TF     TT         NF
     |_____|_____|_____>
     0                      1                       2                    SONRISE
```
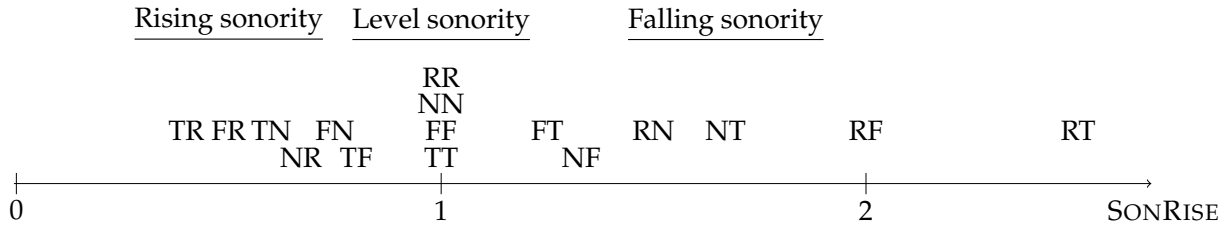
Rose (2000) offers an explanation for these facts in terms of markedness of the sonority contours of the surface clusters. Medial clusters are subject to Syllable Contact, which bans rising sonority clusters across a syllable boundary, while coda clusters are subject to Sonority Sequencing.

The fact that medial clusters are never broken up by epenthesis even when they violate Syllable Contact is due to a constraint against the configuration [V.Cɨ.CV], *MEDIALLIGHT. This constraint is unnecessary under my analysis as the only constraint that would militate against medial clusters, *CODA, is not active.

In addition, Sonority Sequencing does not allow a divide of the [r]-sonorant clusters versus the remainder of the clusters, whether in Rose's categorical formulation of Sonority Sequencing or a family of *DIS constraints.

```
          Rising sonority          Level sonority       Falling sonority
                                        RR        RN         RF        RT
                            NR          NN        NF         NT
                 FR         FN          FF         FT
          TR     TN         TF          TT
     |____|_____|_____|_____|_____|_____|_____|_____>
        -3      -2        -1          0          1          2          3     DIS
```
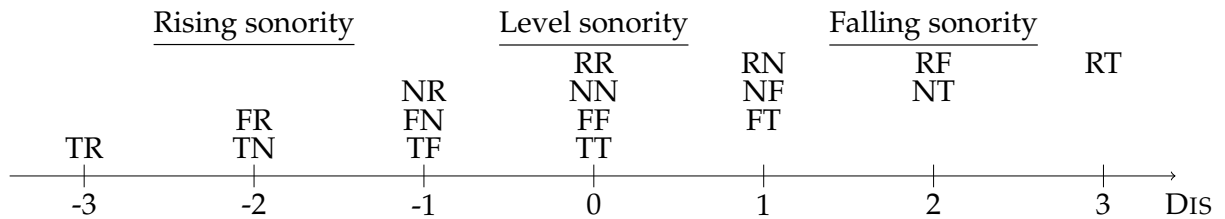
Therefore, Rose needs to invoke the following constraint to cause epenthesis in these clusters:

(54)   *R-SONORANT: no [r]-sonorant sequences (Rose, 2000, (41))

For those speakers that permit obstruent-obstruent clusters in defiance of Sonority Sequencing, Rose ranks Sonority Sequencing low, using the following constraint to trigger epenthesis in other clusters instead:

(55)   *C-SON#: a word-final sonorant consonant must be preceded by a vowel or [r].

Rose's approach thus requires the formulation of two constraints specifically targeting [r]. The advantage of doing so is that it avoids the difficulty of forbidding [βm] clusters which we encountered above. On the other hand, the sonority contour faithfulness approach can get away without specifically mentioning [r] at all, by virtue of the ability of the SONORITY ANGLE hierarchy to group [r]-sonorant clusters together with the level and rising sonority clusters, at the expense of requiring a constraint against [βm] clusters.

4.2 CCC clusters

Triconsonantal clusters are always broken up as [CCɨC] or [CɨCC]. The sources of CCC clusters in Chaha are the 3rd singular masculine conjugation of the jussive form of triliteral verbs, which have the underlying form /jə-CCC-o/, and the 3rd singular masculine conjugation of the passive/reflexive form of quadriliteral verbs, which have the underlying form /j-t-CCaCaC/.

As with coda clusters, there is considerable inter- and intra-speaker variability in epenthetic positioning between idiolects. We begin with data from the main idiolect discussed in Section 4.3 of (Rose, 2000).

4.2.1 Data and Analysis

Triconsonantal clusters must be broken up via epenthesis, indicating that *CCC ≫ DEP. If epenthesis occurs either between C1-C2 or between C2-C3, *CCC will be satisfied. We do not need a separate constraint to prevent double epenthesis occurring to produce *[CɨCɨC].

Input: /CCC/		*CCC	DEP
a.	CCC	*!	
b. ☞	CCɨC		*
c. ☞	CɨCC		*
d.	CɨCɨC		**!

This holds for all the idiolects. Within each idiolect, we need only explain the location of epenthesis.

There are four idiolects to be explained:

(56)   a.   "Default idiolect", discussed in Section 4.3 of (Rose, 2000).
         (i)   [CɨCC] iff C1-C2 is a fall and C2-C3 is a rise or plateau.
         (ii)   [CCɨC] otherwise.
      b.   [CRɨN] idiolect, discussed in Section 5.2.2 of (Rose, 2000).
         (i)   [CCɨC] if C2 is [r] and C3 is a sonorant.
         (ii)   Otherwise as default.
      c.   [CɨCC] idiolect, discussed in Section 5.2.1 of (Rose, 2000).
         (i)   [CCɨC] iff C2-C3 is a fall and C1-C2 is a rise or plateau.
         (ii)   [CɨCC] otherwise.
      d.   [wɨzf, sɨgd] idiolect, discussed in Section 5.2.1 of (Rose, 2000).
         (i)   In this idiolect alone, /wzf/ and /sgd/ epenthesise as [wɨzf] and [sɨgd].

Default idiolect. In the default idiolect (56-a), epenthesis occurs between C2 and C3 to form [CCɨC]. Only when C1-C2 constitutes a sonority rise or plateau, and C2-C3 con-

stitutes a sonority fall, does epenthesis occur between C1 and C2 to form [CᵻCC]. Forms and their associated sonority angles are shown in the table below. Underlined forms have alternate forms in other idiolects.

(57)   Default idiolect

	Underlying form	Surface form	SONANGLE(C1,C2)	SONANGLE(C2,C3)
		Fall-{Rise, Plateau}: [CCᵻC]		
a.	jə-rk't'-o	jənk'ɨt'o	2.36	1.37
b.	jə-rks-o	jənkɨso	2.36	0.59
c.	jə-rk'm-o	jənk'ɨmo	2.36	0.27
d.	jə-<u>wzf</u>-o	jəwzɨfo	2.03	1.33
e.	jə-mxr-o	jəmxɨro	2.03	0.22
f.	jə-<u>sgd</u>-o	jəsgɨdo	2.11	1.37
g.	jə-sdβ-o	jəsdɨβo	2.11	0.18
		{Rise, Plateau}-{Rise, Plateau}: [CCᵻC]		
h.	jə-<u>gdf</u>-o	jəgdɨfo	1.37	0.59
i.	jə-<u>gdr</u>-o	jəgdɨro	1.37	0.12
j.	jə-<u>kmr</u>-o	jəkmɨro	0.27	0.46
k.	jə-<u>sfr</u>-o	jəsfɨro	1.33	0.22
l.	jə-s<u>βr</u>-o	jəsβɨro	0.34	0.73
		Fall-Fall: [CCᵻC]		
m.	jə-rfk-o	jənfɨko	2.03	2.11
n.	jə-rmd-o	jərmɨdo	1.89	2.36
o.	j-a-mst-o	jamsɨto	2.03	2.11
		{Rise,Plateau}-Fall: [CᵻCC]		
p.	jə-kft-o	jəkɨfto	0.59	2.11
q.	jə-dmd-o	jədɨmdo	0.27	2.36
r.	jə-drs-o	jədɨrso	0.12	2.21
s.	jə-<u>k'rm</u>-o	jək'ɨrmo	0.12	1.89
t.	jə-s<u>rβ</u>-o	jəsɨrβo	0.22	1.57
u.	jə-<u>frt</u>-o	jəfɨrto	0.22	2.36
v.	jə-sβx-o	jəsɨβxo	0.34	2.17
w.	j-a-mrg-o	jamɨrgo	0.46	2.36
		Non-jussive forms		
x.	j-t-βt'əbət'	jɨtiβt'əbət'	0.18	2.38
y.	j-t-rsənəs	jɨtɨrsənəs	0.12	2.21
z.	j-t-kβəsəs	jɨtkɨβəsəs	1.37	0.12
A.	j-t-k't'ək'ət'	jɨtk'ɨt'ək'ət'	1.37	1.37

The default preference in this idiolect is to epenthesise on the right, between C2 and C3. I encode this preference with a markedness constraint borrowed from (Rose, 2000)'s analysis:

26

(58)   Align-Left: every consonant must be aligned with the left edge of some prosodic
        word. (Rose, 2000, (21))

Input: /jə-CCC-o/	ALIGN-LEFT
a. jəCiCCo	2,4!,5
b. ☞ jəCCiCo	2,3,5

The only time that ALIGN-LEFT is overruled is when breaking up the C2-C3 cluster
would be too "expensive" in faithfulness terms — when the cluster consists of a sonority
fall — and breaking up the C1-C2 cluster is comparatively cheap, that is, when C1-C2
is a sonority rise or plateau. In SONORITY ANGLE terms, ALIGN-LEFT is overruled only
when breaking the C2-C3 cluster would entail creating a SONORITY ANGLE greater than
1.5, when the alternative of breaking the C1-C2 cluster would create a SONORITY ANGLE
smaller than 1.5.

The ranking IDENT(SONANGLE)<1.5 ≫ ALIGN-LEFT, with all other IDENT(SONANGLE)<n
constraints being ranked lower than markedness, is responsible for the epenthetic posi-
tioning behaviour of this idiolect, as illustrated in the following tableaux.

(59)   IDENT(SONANGLE)<1.5 ≫ ALIGN-LEFT

    a.   Fall-{Rise, Plateau}

Input: /jə-wzf-o/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. ☞ jəwzɨfo	1.33	
b. jəwizfo	2.03 *!	*

    b.   {Rise, Plateau}-{Rise, Plateau}

Input: /jə-gdf-o/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
c. ☞ jəgdɨfo	1.37	
d. jəgɨdfo	0.59	*!

    c.   Fall-Fall

Input: /j-a-mst-o/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
e. ☞ jamsɨto	2.11 *	
f. jamɨsto	2.03 *	*!

    d.   {Rise, Plateau}-Fall

Input: /jə-kft-o/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
g. jəkfɨto	2.11 *!	
h. ☞ jəkɨfto	0.59	*

Remark on conflation. Notice that all distinctions among the set of rising and level sonority clusters on the one hand, and the distinctions among the set of falling sonority clusters, are conflated. For instance, consider the cluster /mst/. SONANGLE(m,s), at 2.03, is smaller than SONANGLE(s,t), at 2.11, yet epenthesis occurs on the right, creating the larger SONORITY ANGLE. This is because the distinction between SONORITY ANGLES of 2.03 and 2.11 is irrelevant under the given constraint ranking, since both 2.03 and 2.11 violate the relevant faithfulness constraint IDENT(SONANGLE)<1.5. This is possible because I have adopted the position that the IDENT(SONANGLE)<n constraints can be freely ranked.

Adopting the converse strategy — that IDENT(SONANGLE)<n constraints have a universal ranking — would not predict [msɨt]. Instead we would have the following situation:

(60)   Universal ranking cannot derive [jamsɨto]

Input: /j-a-mst-o/	IDENT(SONANGLE)<2.1	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. ☹ jamsɨto	2.11 *!	2.11 *	
b. ☞ jamɨsto	2.03	2.03 *	*

[CRɨN] idiolect. In a second idiolect (56-b) (c.f. Section 5.2.2 of (Rose, 2000)), clusters behave much as in the default, except that when C2 is [r] and C3 is sonorant, epenthesis occurs on the right instead.

(61)   a.   jək'rɨmo 'let them insult'
        b.   jəsrɨβo 'let them break'

The explanation for the special behaviour of RN clusters among triconsonantal clusters in this idiolect is similar to that of RN clusters among coda clusters: the dividing line between the conflated clusters has simply shifted to the right, at 1.9, grouping RN clusters together with sonority rises and plateaus, versus all other falls. This is possible using the SONORITY ANGLE metric because RN clusters are expected to be the most susceptible to epenthesis of all the falling sonority clusters.

(62)   a.   Behaviour of clusters with C2=/r/ and C3=sonorant under idiolect (56-a):

Input: /jə-krm-o/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. jəkrimo	1.89 *!	
b. ☞ jəkirmo	0.12	*

        b.   Behaviour of clusters with C2=/r/ and C3=sonorant under idiolect (56-b):

Input: /jə-krm-o/	IDENT(SONANGLE)<1.9	ALIGN-LEFT
a. ☞ jəkrimo	1.89	
b. jəkirmo	0.12	*!

As a consequence of this, however, we would incorrectly expect a cluster like /rmd/ to epenthesise on the left:

(63)

Input: /jə-rmd-o/	IDENT(SONANGLE)<1.9	ALIGN-LEFT
a. ☺ jərmido	2.36 *!	
b. ☞ jərimdo	1.89	*

Looking across the clusters, we find that all /r/-initial and /n/-initial triconsonantal clusters epenthesise as [CCɨC]. This seems to be due to a morphophonological constraint, as Rose states that "[t]here is an independent requirement that if the initial root consonant of a triliteral root is /r/, it must appear in a coda in the jussive, realised as [n], except where there is a nasal in the root." (412, fn. 20). In addition, all [n]-initial roots are underlyingly /r/ (Banksira, 2000, 22), and the only possible sources of /r/ or [n]-initial triconsonantal clusters in the language are jussive forms, so there is no independent evidence of how these clusters would epenthesise in the absence of this requirement.

Adopting the following undominated constraint in Chaha, therefore, guarantees the correct form for all /r/ and [n]-initial clusters, including /rmd/ in this instance.

(64)   JUSSIVE-R: if the first consonant of the input root is /r/, its output correspondent must be in the coda in the jussive.

(65)   JUSSIVE-R ≫ IDENT(SONANGLE)<1.9 ≫ ALIGN-LEFT

Input: /jə-rmd-o/	JUSSIVE-R	IDENT(SONANGLE)<1.9	ALIGN-LEFT
a. ☞ jərmido		2.36 *	
b. jərimdo	*!	1.89	*

Rose also uses the JUSSIVE-R constraint in her analysis of quadriconsonantal clusters. This ranking explains all the forms in the second idiolect.

[CɨCC] idiolect. In the third idiolect (56-c) (c.f. Section 5.2 of of (Rose, 2000)), most clusters epenthesise as [CɨCC]. This includes clusters

(66)   Default idiolect

	Underlying form	Surface form	SonAngle(C1,C2)	SonAngle(C2,C3)
	Fall-{Rise, Plateau}: [CCɨC]			
a.	jə-rk'tʼ-o	jənk'ɨtʼo	2.36	1.37
b.	jə-rks-o	jənkɨso	2.36	0.59
c.	jə-rk'm-o	jənk'ɨmo	2.36	0.27
d.	jə-w̲z̲f̲-o	jəwzɨfo	2.03	1.33
e.	jə-mxr-o	jəmxɨro	2.03	0.22
f.	jə-s̲g̲d̲-o	jəsgɨdo	2.11	1.37
g.	jə-s̲d̲β̲-o	jəsdɨβo	2.11	0.18
	{Rise, Plateau}-{Rise, Plateau}: [CɨCC]			
h.	jə-g̲d̲f̲-o	jəgɨdfo	1.37	0.59
i.	jə-g̲d̲r̲-o	jəgɨdro	1.37	0.12
j.	jə-k̲m̲r̲-o	jəkɨmro	0.27	0.46
k.	jə-s̲f̲r̲-o	jəsɨfro	1.33	0.22
l.	jə-s̲β̲r̲-o	jəsɨβro	0.34	0.73
	Fall-Fall: [CCɨC]			
m.	jə-rfk-o	jənfɨko	2.03	2.11
n.	jə-rmd-o	jərmɨdo	1.89	2.36
o.	j-a-mst-o	jamsɨto	2.03	2.11
	{Rise,Plateau}-Fall: [CɨCC]			
p.	jə-kft-o	jəkɨfto	0.59	2.11
q.	jə-dmd-o	jədɨmdo	0.27	2.36
r.	jə-drs-o	jədɨrso	0.12	2.21
s.	jə-k̲'r̲m̲-o	jək'ɨrmo	0.12	1.89
t.	jə-s̲r̲β̲-o	jəsɨrβo	0.22	1.57
u.	jə-f̲r̲t̲-o	jəfɨrto	0.22	2.36
v.	jə-s̲β̲x̲-o	jəsɨβxo	0.34	2.17
w.	j-a-mrg-o	jamɨrgo	0.46	2.36

In this idiolect, the default preference is to epenthesise as [CɨCC], but this is overridden when C2-C3 constitutes a sonority rise or plateau, and C1-C2 constitutes a sonority fall.

This calls for a different active markedness constraint than ALIGN-LEFT. Again borrowing from Rose, I utilise the following constraint:

(67) Anchor-Left Root: An element at the left edge of the root corresponds to an element at the left edge of a heavy syllable. (Rose, 2000, (45))

Input: /jə-CCC-o/	ANCHOR-LEFT Rt
a. jə.CɨC.Co	
b. ☞ jəC.Cɨ.Co	*

Armed with this constraint, we can cast this behaviour as the following ranking in SONORITY ANGLE terms:

(68)   IDENT(SONANGLE)<1.5 ≫ ANCHOR-LEFT ROOT
    a.   Fall-{Rise, Plateau}

Input: /jə-wzf-o/	IDENT(SONANGLE)<1.5	ANCHOR-L RT
a. ☞ jəwzɨfo	1.33	*
b. jəwizfo	2.03 *!	

    b.   {Rise, Plateau}-{Rise, Plateau}

Input: /jə-gdf-o/	IDENT(SONANGLE)<1.5	ANCHOR-L RT
c. jəgdɨfo	1.37	*!
d. ☞ jəgɨdfo	0.59	

    c.   Fall-Fall

Input: /j-a-mst-o/	IDENT(SONANGLE)<1.5	ANCHOR-L RT
e. jamsɨto	2.11 *!	
f. ☞ jamɨsto	2.03 *	*

    d.   {Rise, Plateau}-Fall

Input: /jə-kft-o/	IDENT(SONANGLE)<1.5	ANCHOR-L RT
g. jəkfɨto	2.11 *!	*
h. ☞ jəkɨfto	0.59	

This ranking predicts that fall-fall clusters should epenthesise on the left. Items (m) and (n) are accounted for as they are subject to the JUSSIVE-R constraint, but the /mst/ cluster in (o) is predicted to surface as [mɨst], whereas Rose marks it as being epenthesised as [msɨt] without variation. On the other hand, one of Rose's constraint rankings produces this form. Moreover, Degif Petros Banksira (p.c.), a native speaker of Chaha, confirms that he produces the form [jamɨsto]. Therefore this prediction actually proves correct.

[wɨzf, sɨgd **idiolect.**] There still remain two clusters whose alternative behaviour remains unexplained according to the rankings we have obtained so far.

(69)   a.   /jə-wzf-o/ can surface as [jə-wɨzf-o], but this is not predicted by any ranking so far, including (68)

Input: /jə-wzf-o/	IDENT(SONANGLE)<1.5	ANCHOR-L ROOT
a. ☹ jəwɨzfo	2.03 *!	
b. ☞ jəwzɨfo	1.32	*

b. /jə-sgd-o/ can surface as [jə-sɨgd-o], but this is not predicted by any ranking so far, including (68)

Input: /jə-sgd-o/	IDENT(SONANGLE)<1.5	ANCHOR-L ROOT
c. ☹ jəsɨgdo	2.11 *!	
d. ☞ jəsgɨdo	1.37	*

These two datapoints can be explained by retaining the constraint ranking of idiolect 3, but moving the dividing line to 1.0, between sonority rises on the one hand, and sonority plateaus and falls on the other.

This behaviour is equivalent to the following SONORITY ANGLE-based ranking:

(70)   IDENT(SONANGLE)<1.0 ≫ ANCHOR-L-ROOT

a.

Input: /jə-wzf-o/	IDENT(SONANGLE)<1.0	ANCHOR-L ROOT
a. ☞ jəwɨzfo	2.03 *	
b. jəwzɨfo	1.32 *	*!

b.

Input: /jə-sgd-o/	IDENT(SONANGLE)<1.0	ANCHOR-L ROOT
a. ☞ jəsɨgdo	2.11 *	
b. jəsgɨdo	1.37 *	*!

In summary, we were able to explain all four CCC idiolects of Chaha by ranking different IDENT(SONANGLE)<n constraints higher than either ALIGN-LEFT or ANCHOR-LEFT ROOT.

4.2.2 Comparison with alternative approaches

The analysis of the four idiolects above was possible because the lines at which faithfulness conflation occur in Chaha correspond to linear separations of the various sets of clusters:

(71)   a.   Idiolect (56-a) (sonority rises and plateaus) vs (sonority falls)
        b.   Idiolect (56-b): (sonority rises and plateaus and RN) vs (other sonority falls)
        c.   Idiolect (56-c): (sonority rises and plateaus) vs (sonority falls)
        d.   Idiolect (56-d): (sonority rises) vs (sonority plateaus and falls)

The Sonority Rise metric can achieve the same linear separation for idiolects 1, 3 and 4, but notice that this is not possible for idiolect (56-b), because Sonority Rise cannot achieve a linear separation of the sonority rises, plateaus and RN from the remainder of the falling sonority clusters.

Rose (2000) presents a successful analysis of the same data in Chaha, from which I have liberally borrowed. Under her approach, it is Syllable Contact that triggers epenthesis. To this end, she employs two versions of Syllable Contact that achieve the grouping effect above. The first permits sonority falls, while the second, looser constraint, permits both sonority falls and plateaus.

(72)   a.   SYLLCON: The first segment of the onset of a syllable must be lower in sonority
       b.   SYLLCON(LOOSE): The first segment of the onset of a syllable must not be of greater sonority than the last segment of the immediately preceding syllable.

Variable placement of these two constraints with respect to ALIGN-LEFT and ANCHOR-LEFT ROOT, which themselves can be variably ranked, predict three of the four idiolects.

(73)   Rose's constraint rankings for idiolects (56-a), (56-c) and (56-d).
       a.   Idiolect (56-a): SYLLCON ≫ DEP ≫ ALIGN-L ≫ ANCHOR-L ROOT
            (i)   [CCɨC] unless C1-C2 violates SYLLCON (is a sonority rise or plateau) and C2-C3 would not.
       b.   Idiolect (56-c): SYLLCON ≫ DEP ≫ ANCHOR-L ROOT ≫ ALIGN-L
            (i)
            CɨCCunless C2-C3 violates SYLLCON (is a sonority rise or plateau) and C1-C2 would not.
       c.   Idiolect (56-d): SYLLCON(LOOSE) ≫ DEP ≫ ANCHOR-L ROOT ≫ ALIGN-L ≫ SYLLCON
            (i)   [CɨCC] unless C2-C3 violates SYLLCON(LOOSE) (is a sonority rise) and C1-C2 would not.

Thus far, the logic has been very similar to the SONORITY ANGLE analysis. Explaining the special behaviour of RN clusters in the [CRɨN] idiolect (56-b), requires invoking the *R-SON constraint used in the analysis of idiolects (47-b) and (47-d) of the coda clusters.

(74)   Rose's constraint ranking for the [CRɨN] idiolect (56-b)
       a.   *R-SON ≫ SYLLCON ≫ DEP ≫ ALIGN-L ≫ ANCHOR-L ROOT

In addition to these, the *MEDIALLIGHT constraint from Rose's analysis of the medial two-consonant clusters must again be invoked to prevent double epenthesis forming [CɨCɨC] in the case where both C1-C2 and C2-C3 constitute violations of SYLLCON.

4.3 CCCC clusters

In this last part of our case study of Chaha, we turn to the behaviour of quadriconsonantal clusters. The only such clusters come from the imperative/jussive CCC stem followed by the consonant-initial suffix -nə. The underlying form is /n-ɕɕɕ-nə/. They surface either as [nɨCCɨCnə] or [nɨCɨCCɨnə].

In this section, I will demonstrate that the rankings already obtained for CCC clusters predict almost exactly which of the CCCC clusters should display variation and in which direction.

4.3.1 Predictions of CCC rankings

The undominated nature of the constraint *CCC, which we used to trigger epenthesis among the triconsonantal clusters, also triggers epenthesis in quadriconsonantal clusters. This excludes possible solutions such as *[CɨCCC] and *[CCCɨC], as these still incur a violation of *CCC.

Solutions such as [CɨCɨCC] and [CCɨCɨC] are also excluded, as these incur unnecessary violations of IDENT(SONANGLE) and DEP. If the middle two consonants C2 and C3 are split up by an epenthetic vowel, there is no further need for epenthesis as *CCC is already satisfied by [CCɨCC].

Therefore, the only two possible solutions under my approach are [CCɨCC] and [CɨCCɨC]. Which one is chosen depends on the sonority profile of the clusters, and which of ALIGN-LEFT and ANCHOR-LEFT ROOT is dominant.

(75)   ALIGN-LEFT favours [CCɨCC], but ANCHOR-LEFT RT favours [CɨCCɨC].

Input: /n-CCC-nə/		Align-Left	Anchor-Left Root
a.	nɨC.CɨC.nə	2,3,5,6	*
b. ☞	nɨ.CɨC.Cɨ.nə	2,4!,5,7	

There are some clusters whose epenthetic behaviour is subject to other considerations. The constraint JUSSIVE-R still applies to these forms, for example, which ensures that the following forms epenthesise as [CCɨCC]:

(76)   a.   nɨ-nk'ɨm-nə
        b.   nɨ-nfɨk-nə
        c.   nɨ-rmɨd-nə
        (Rose, 2000, (33a,34a,34b))

In addition, Chaha prohibits intramorphemic geminates, which enforces the following forms:

(77)   a.   nɨ-k'fɨfnə

b. nɨ-sdɨdnə
    (Rose, 2000, (37a,b))

I will not consider such clusters further.

Given the general form of the ranking IDENT(SONANGLE)<n ≫ ALIGN-LEFT ≫ ANCHOR-LEFT ROOT, the expected behaviour of four-consonant clusters is as follows: all /CCCC/ clusters surface as [CCɨCC], except when SONANGLE(C2,C3) exceeds n and SONANGLE(C1,C2) and SONANGLE(C3,C4) are both smaller than n. Illustrative tableaux are shown below for n=1.5:

(78) IDENT(SONANGLE)<1.5 ≫ ALIGN-LEFT
   a. Case 1: SONORITY ANGLE(C2,C3)<1.5

Input: /n-gdf-nə/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. ☞ nɨgdɨfnə	0.59	
b. nɨgɨdfɨnə	1.37, 0.54	*!

   b. Case 2: SONORITY ANGLE(C2,C3)>=1.5 but so is one of SONORITY AN-GLE(C1,C2) or SONORITY ANGLE(C3,C4)

Input: /n-srβ-nə/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. ☞ nɨsrɨβnə	1.57 *	
b. nɨsɨrβɨnə	0.22, 1.65*	*!

   c. Case 3: SONORITY ANGLE(C2,C3)>=1.5 and both SONORITY ANGLE(C1,C2) and SONORITY ANGLE(C3,C4)<1.5

Input: /n-dmd-nə/	IDENT(SONANGLE)<1.5	ALIGN-LEFT
a. nɨdmɨdnə	2.3 *!	
b. ☞ nɨdɨmdɨnə	0.27, 0.27	*

Given the general form of the ranking IDENT(SONANGLE)<n ≫ ANCHOR-LEFT ROOT ≫ ALIGN-LEFT, the default behaviour is to epenthesise as [CɨCCɨC]. This preference is overridden when at least one of SONANGLE(C1,C2) and SONANGLE(C3,C4) are greater than n and SONANGLE(C2,C3) is less than n.

(79) IDENT(SONANGLE)<1.5 ≫ ANCHOR-LEFT RT
   a. Case 1: Both SONORITY ANGLE(C1,C2) and SONORITY ANGLE(C3,C4)<1.5

Input: /n-gdf-nə/	IDENT(SONANGLE)<1.5	ANCHOR-LEFT RT
a. nɨgdɨfnə	0.59	∗!
b. ☞ nɨgɨdfɨnə	1.37, 0.54	

b.   Case 2: SONORITY ANGLE(C1,C2) or SONORITY ANGLE(C3,C4) >=1.5, but so is SONORITY ANGLE(C2,C3)

Input: /n-srβ-nə/	IDENT(SONANGLE)<1.5	ANCHOR-LEFT RT
a. nɨsriβnə	1.57 ∗	∗!
b. ☞ nɨsɨrβɨnə	0.22, 1.65∗	

c.   Case 3: SONORITY ANGLE(C1,C2) or SONORITY ANGLE(C3,C4) >=1.5, and SONORITY ANGLE(C2,C3)<1.5

Input: /n-sdβ-nə/	IDENT(SONANGLE)<1.5	ANCHOR-LEFT RT
a. ☞ nɨsdiβnə	0.18	∗
b. nɨsɨdβɨnə	2.11 ∗!, 1.65 ∗	

The following table shows the actual surface forms observed for each of the underlying clusters, as well as the predictions of the four idiolectal rankings.

(80)   Table of CCCC clusters, observed outcomes and predictions made by the constraint rankings proposed for the four idiolects in §4.2.1.

	SONANGLES				PREDICTIONS OF IDIOLECT			
Cluster	C1,C2	C2,C3	C3,C4	Observed outcomes	1	2	3	4
a. sdβn	2.11	0.18	1.66	sdiβn		sdiβn		
b. wzfn	2.03	1.33	0.54	wzfn, wɨzfɨn		wzfn		wɨzfɨn
c. gdfn	1.37	0.59	0.54	gdifn, gɨdfɨn		gdifn	gɨdfɨn	gdifn
d. mstn	2.03	2.11	0.27	mistɨn	*msɨtn		mistɨn	
e. dmdn	0.27	2.36	0.27	dimdɨn		dimdɨn		
f. drsn	0.12	2.21	0.54	dirsɨn		dirsɨn		
g. sβxn	0.34	2.17	0.54	siβxɨn		siβxɨn		
h. kftn	0.59	2.11	0.27	kiftɨn		kiftɨn		
i. ktfn	1.37	0.59	0.54	ktifn, kɨtfɨn		ktifn	kɨtfɨn	ktifn
j. sgdn	2.11	1.37	0.27	sgɨdn, sɨgdɨn		sgɨdn		sɨgdɨn
k. srβn	0.22	1.57	1.65	sriβn, sɨrβɨn		sriβn		sɨrβɨn
l. krmn	0.12	1.89	1.25	krimn, kɨrmɨn	kɨrmɨn	krimn		kɨrmɨn

There is only one incorrect prediction, namely that /mstn/ should surface as [msɨtn] in idiolects (56-a) and (56-b), but Rose indicates that there is no variation. It is possible

that this is simply a form that does undergo variation but the predicted [msɨtn] variant has not been observed in Rose's corpus.

Apart from the case of /mstn/, we see that the predictions of the rankings derived for the /CCC/ case are quite successful: clusters predicted to show variation do show variation, while for those predicted to surface only as one of [CCɨCC] and [CɨCCɨC], the predicted form is indeed the only one observed.

4.4 Summary: Chaha

In this case study, I presented an alternative analysis of Chaha epenthetic positioning to Rose (2000)'s Syllable Contact-based analysis, in which sonority profiles affected epenthesis via the mechanism of sonority-based faithfulness constraints IDENT(SONANGLE)<n rather than sonority-based markedness constraints such as Syllable Contact and Sonority Sequencing. The fact that general constraints on syllable structure such as *CCC and *COMPLEXCODA drove epenthesis eliminated the need for constraints forbidding too much epenthesis, as Rose does in the form of the constraint *MEDIALLIGHT.

The prediction of SONORITY ANGLE that RN clusters should be the most susceptible of all the falling sonority clusters to epenthesis was borne out in the Chaha data, both in CC# and CCC clusters. This fact made it possible for us to do without Rose's *R-SON constraint, although at the expense of requiring a constraint against [βm] clusters. Invoking another faithfulness constraint, DEP(+son), in the analysis of CC# clusters allowed us to eliminate the use of Rose's *C-SON constraint, which also needed to make special reference to [r].

In the final tally, the SONORITY ANGLE-based approach fares worse on one datapoint and uses approximately the same number of constraints, but manages to accomplish most of the work of the analysis with the only crucial ranking being the placement of a single IDENT(SONANGLE)<n constraint with respect to a relevant $\mathcal{M}$ constraint, while in Rose's analysis this work is spread over a number of different sonority-related constraints.

5 Discussion

In this paper, I proposed two desiderata for a metric of sonority contour distance, and suggested SONORITY ANGLE as a concrete metric that fit these criteria. In this section, I examine first a general question regarding sonority contour faithfulness, then discuss weaknesses of SONORITY ANGLE as a metric, as well as possible extensions of this metric to domains beyond sonority-driven epenthesis.

6 Disregarding V-C2

In the sonority contour faithfulness approach, the relevant comparison is between C1-C2 and C1-V. But why these two vectors? In particular, why not C1-C2 versus V-C2?

(81)   Left: SONORITY ANGLE as currently defined; right: another possible definition as the angle C1-C2-V.
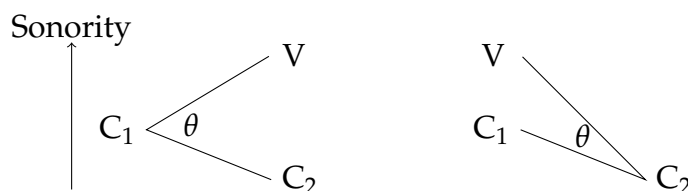
The answer, currently, is based purely on empirical grounds: if we assume this comparison to be the relevant one, then we expect falling sonority contours to be more susceptible to epenthesis, which contradicts the cross-linguistic evidence. It would seem that there is something quite fundamental about the comparison being centred around the rightward context, or release, of C1, which may perhaps arise out of phonological processing.

6.1 Robustness of the metric

Changes in C1. In the discussion of Chaha triconsonantal clusters in §4.2.1, I glossed over how the metric should be computed if C1 changes. This was an issue in clusters such as /rfk/, which emerge as [nfɨk] due to morphophonological processes. Ultimately, this was not an issue because the behaviour of all such clusters was independently determined by JUSSIVE-R, but this raises the question of how SONORITY ANGLE should be computed if C1 changes. Currently, it is undefined, as it is unclear how to measure the angle between C1-C2=RF and C1-V=NV:

(82)
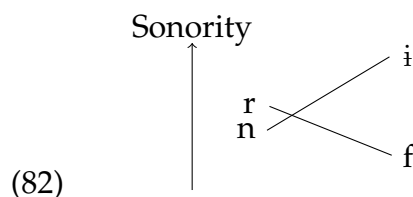
It is of course possible to define the angle as whatever is made by the intersection of the two vectors, but there is insufficient data to support this interpretation. Alternative approaches such as SONORITY RISE do not face this issue, as computing the gradients of the underlying contour /C1C2/ and the surface contour [C1V] does not depend on the two C1's being the same.

Horizontal distance. In this paper, I assumed that the horizontal distance between C1 and C2, and C1 and V, is the same, and arbitrarily fixed at 1 unit, in calculating SONORITY ANGLE. This is an arbitrary choice, and potentially an important one, as when the horizontal distance gets large, changes occur in the cluster hierarchy, some of which violate the first desideratum for a sonority angle metric:

(83)   SONORITY ANGLE hierarchy for a horizontal distance of 100 units.

RR	RN	RF	RT
NR	NN	NF	NT
FR	FN	TF	FT
TR	TN	FF	TT

$$\xrightarrow{\hspace{8cm}}$$
SONANGLE
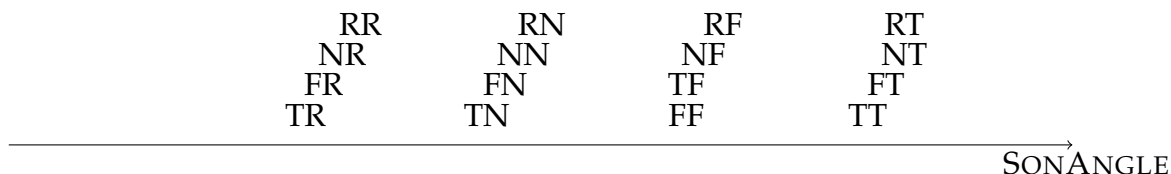
Notice that we cannot achieve a clean separation of the rising versus level versus falling sonority clusters, as before. Compare this with SONORITY RISE which, being dimensionless (since it is the ratio of two vectors in the same plane), does not have to take into account such units.

Additionally, since this horizontal distance is along the dimension of time, the assumption that the two horizontal distance for C1-C2 is the same as that for C1-V is likely incorrect. If we choose different values for these two horizontal distances, the cluster hierarchy would also be likely to change. This would also be a consideration to take into account when computing SONORITY RISE.

Arbitrariness of the sonority scale. A third issue faced by any sonority metric is the arbitrariness of the vertical, sonority scale used in this paper. The scale adopted, which is a relatively standard scale, is rather phonological in nature, placing each sonority class at a distance of 1 from the next, and ignoring all differences between consonants within each class. From a phonetic standpoint, this seems unlikely. Observe, for example, the values obtained by Parker (2002) for ???, the metric that Parker found to be the most correlated with phonological sonority:

(84)   TODO: Parker sonority scale

Plugging this scale into the SONORITY ANGLE metric, we obtain

Ultimately, the most practical course of action may be to simply attempt to experimentally determine sonority contour distances, and perhaps then fit them to a metric. To date, only a few sonority contour distances have been experimentally determined, for example between rising (TR) and falling (sT) clusters (Fleischhacker, 2002), but not finer-grained distances such as between the various falling sonority clusters. I leave this to future work.

6.2   Extensions of the metric

So far, I have employed the SONORITY ANGLE metric purely in the analysis of sonority-driven epenthesis. However, there are other possible applications.

Syncope. We can straightforwardly adapt the sonority contour faithfulness account to analyse syncope, as pointed out by Flemming (2008). Interestingly, this makes different predictions from an account based on Syllable Contact, unlike the case of epenthesis where sonority contour faithfulness and Syllable Contact make similar predictions.

According to Syllable Contact, syncope should be blocked when it would create a marked, rising sonority, cluster. We expect syncope to preferentially create falling sonority clusters. Under a sonority contour faithfulness account, however, we expect clusters to be created when they are similar in sonority profile to the underlying C1-V contour – that is, rising sonority clusters should be preferentially created.

Flemming (2008) cites two cases of sonority-sensitive syncope in English and Dutch in which rising sonority clusters are preferentially created. Illustrative examples from English are given below:

(85)   a.   Syncope allowed when rising sonority cluster is created
          (i)   ɛvəri ~ ɛvri 'every'
          (ii)   mɛməri ~ mɛmri 'memory'
    b.   Syncope disallowed when level or falling sonority cluster would have been created
          (i)   pɪkətɪŋ ~ pɪktɪŋ 'picketing'
          (ii)   kəpæsəti ~ kəpæsti 'capacity'
          (Data from (Hooper, 1978), cited in (Flemming, 2008))

On the other hand, syncope in Hebrew (Landau, 1997), Lushootseed (Urbanczyk, 1996) and Mantuan (Miglio, 1998) are said to work according to the principles of Syllable Contact:

(86)   a.   Syncope allowed when falling sonority cluster is created
          (i)   šomér-et   + otó → šoméretotò (no deletion) / šomértotò
               keep-3SgFem + it
          (ii)   kibél   + otáx → kilbéltax
               accept.3SgMasc + you
    b.   Syncope disallowed when rising sonority cluster would have been created
          (i)   hevé-tem + otó → hevétemotò (no deletion) / *hevétmotò
               bring-2pl + it
          (ii)   xašav   + aláv   → *xašávlav
               think.3SgMasc + about.him
          (Data from (Landau, 1997))

More work needs to be done to reconcile these two types of sonority-driven syncope.

Consonant deletion. The current formulation of IDENT(SONANGLE)<n constraints restricts its application to when the consonants of a C1-C2 and C1-V-C2 sequence stand in correspondence. However, another formulation is possible, in which sonority contours are a property of C1 rather than a property of the whole contour.[3]

(87)   TODO: formulate this

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[3]Thanks to Adam Albright for this suggestion.

A possible application of this looser definition of SONORITY ANGLE lies in the deletion of consonants in complex onsets.

7 Conclusion

In this paper, I argued for sonority contour faithfulness being the right way to analyse sonority-driven epenthesis, giving case studies in Irish and Chaha as examples. I additionally proposed that sonority contour distance should be computed by a metric that obeys two desiderata,

Using SONORITY ANGLE as a concrete example of a metric that obeys these two desiderata, I showed that a sonority contour faithfulness account based on SONORITY ANGLE worked better than a cluster markedness-based account of sonority-driven epenthesis in Irish. Firstly, the faithfulness-based analysis did not need separate constraints for heterosyllabic and coda clusters like Syllable Contact and Sonority Sequencing, which more economically accounted for the "coincidence" that the same clusters were allowed and disallowed in both syllabic contexts. Secondly, the markedness-based approach in Irish could not account for why obstruent-initial heterosyllabic and coda clusters are tolerated in Irish even though these should be more marked than sonorant-initial clusters under the two sonority-based markedness constraints.

In addition, compared to the *DIS metric (Gouskova, 2002) for measuring sonority distance in Syllable Contact and Sonority Sequencing, and the alternative sonority contour faithfulness metric SONORITY RISE (Flemming, 2008), SONORITY ANGLE made the correct predictions that nasal-voiceless stop and liquid-voiceless stop clusters should be the hardest to epenthesise into in Irish, and the prediction that liquid-nasal clusters should be the most susceptible to epenthesis out of the falling sonority clusters in Chaha.

SONORITY ANGLE was offered here as a concrete instance of the class of metrics that conform to the two desiderata. In §5, I discussed several issues regarding the assumptions that need to be incorporated into its formulation. More perceptual experiments and cross-linguistic investigation of sonority-driven epenthesis needs to be done to pin down the specifics of the metric. In addition, I discussed two other sonority-based phenomena that may shed additional light on the true nature of sonority contour faithfulness.

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