The Perceptual Dimensions of Sonority-Driven Epenthesis*

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1 Introduction

Vowel epenthesis often appears to preferentially target consonant clusters with rising sonority, as in the following example of English loanwords borrowed into Hawai'ian creole. The rising sonority onset cluster is adapted with epenthesis, while the falling sonority cluster is left intact.

(1)   a.   puranti: 'plenty'
       b.   ste: 'stay'
       (Nagara (1972), cited by Fleischhacker (2005))

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 into than falling sonority sibilant-stop clusters.

The second broad class of explanation for sonority-driven epenthesis is markedness-based: rising sonority clusters are marked in comparison with sonority falls, and thus more susceptible to any repair, including epenthesis. Constraints targeting rising sonority clusters are usually defined by syllabic context: Sonority Sequencing (Selkirk, 1984) in codas and Syllable Contact (Murray & Vennemann, 1983) across syllable boundaries.

In this paper, I argue for the sonority contour faithfulness-based approach over the markedness approach using two case studies of sonority-driven epenthesis in Irish and Chaha.

The perceptual faithfulness 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 values of C_1, C_2 and V. Fleischhacker's analysis rested on empirical determinations of sonority contour faithfulness of specific clusters such as stop-liquid (TR) clusters and fricative-stop (FT) clusters, and did not attempt to determine a formula for arbitrary values of C_1 and C_2. 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 propose an alternative metric, SONORITY ANGLE, the magnitude of the angle formed by the contours $/C_1C_2/$ and $[C_1V]$. Given a sonority scale, this metric makes concrete predictions as to the hierarchy of susceptibility of consonant clusters to epenthesis, which differ from those of SONORITY RISE (Flemming, 2008) and also from the predictions of gradient-based versions of Syllable Contact such as *DIS (Gouskova, 2002).

Two specific predictions of SONORITY ANGLE, namely that (i) nasal-stop and liquid-stop clusters should be the hardest to epenthesise into, and (ii) that liquid-nasal clusters should be the easiest of the falling sonority clusters to epenthesise into, are borne out in the case studies of Irish and Chaha respectively.

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2   SONORITY ANGLE and its predictions

SONORITY ANGLE is defined as the angle between the underlying /C_1C_2/ sonority contour and the surface [C_1V] contour:

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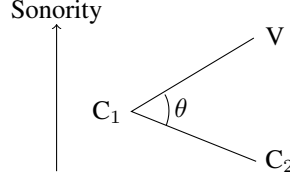
Assuming that the horizontal distance is 1 unit, we can compute the magnitude of this angle analytically with the following formula:

(3)   Formula: SON∡ $= \arctan(V - C_1) - \arctan(C_2 - C_1)$

We can formalise the idea of SONORITY ANGLE as a faithfulness cost by defining a family of IDENT constraints that penalise outputs that incur faithfulness costs greater than a certain n, following Flemming (2008).

(4)   IDENT(SON∡)<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.

One consequence of choosing this metric of sonority contour distance is that for any given C_1, the higher the sonority of C_2, the easier it is to break up the cluster via epenthesis as the faithfulness cost of doing so, in terms of SONORITY ANGLE, is small. This is illustrated in the diagram on the left in (5): falling sonority nasal-stop (NT) has a larger SONORITY ANGLE θ_1 than rising sonority nasal-liquid (NR).

A second consequence is that for any two clusters with the same sonority distance, the one with the more sonorous consonants will have the smaller SONORITY ANGLE and hence be more susceptible to epenthesis. This is illustrated in the diagram on the right: despite the fact that liquid-nasal (RN) and fricative-stop (FT) clusters are one step apart on the standard sonority scale that we assume in this paper, RN has a smaller SONORITY ANGLE θ_2 than the less sonorous FT.

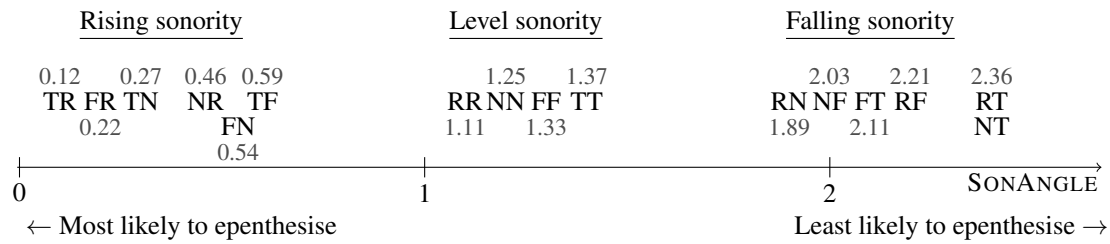(5)   Consequences of the SONORITY ANGLE metric
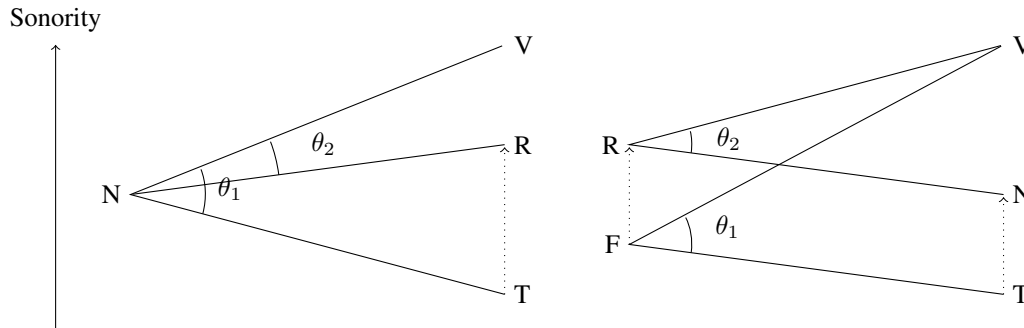
The first consequence is clearly a desirable property for the metric, as it encodes the fundamental observation with which we began, that vowel epenthesis should target rising sonority clusters as these have smaller SONORITY ANGLES. The second consequence is reflected in the epenthesis patterns of Irish and Chaha.

2.1   *Comparison of predictions*   Given a standard sonority scale as in (6) (Flemming, 2008), we can derive a hierarchy of clusters in terms of their predicted susceptibility of epenthesis, which is given in (7).

(6)

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

2

(7)   SONORITY ANGLE hierarchy

Rising sonority	Level sonority	Falling sonority

```
  0.12   0.27  0.46  0.59          1.25   1.37              2.03   2.21  2.36
  TR FR TN    NR   TF            RR NN FF  TT              RN NF FT RF     RT
     0.22            FN          1.11   1.33               1.89    2.11    NT
                     0.54
```

0   1   2   SONANGLE

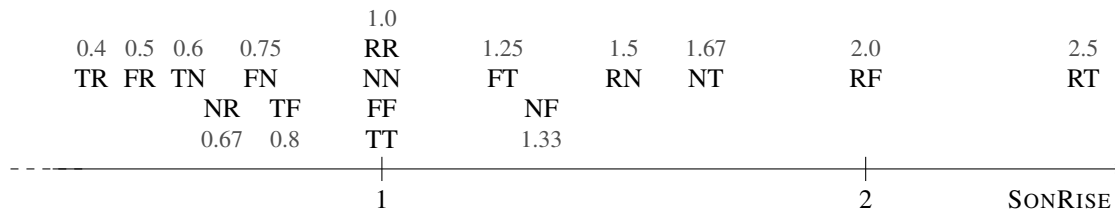← Most likely to epenthesise   Least likely to epenthesise →

Observe that the NT and RT clusters are predicted to be the hardest to epenthesise into of all the clusters. Of the falling sonority clusters, RN should be the easiest to epenthesise into.

Contrast this with the predictions of the competing sonority contour distance metric SONORITY RISE (Flemming, 2008), which is defined as 1 minus the ratio of the underlying and output gradients:

(8) $\text{SONRISE} = 1 - \frac{C_2 - C_1}{V - C_1}$

This gives rise to the following hierarchy of clusters:

(9)   SONORITY RISE hierarchy

```
                              1.0
  0.4  0.5  0.6    0.75       RR        1.25      1.5   1.67          2.0                 2.5
  TR  FR  TN     FN          NN        FT       RN   NT            RF                  RT
         NR    TF           FF                   NF
         0.67   0.8        TT          1.33
```

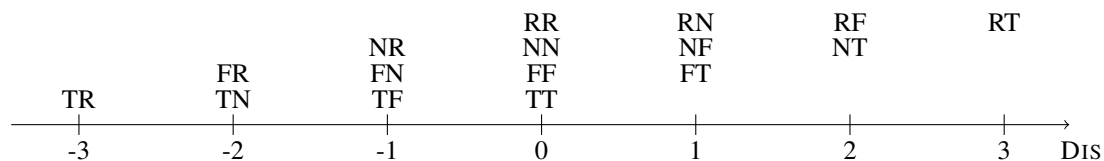1   2   SONRISE

Notice that while the RT cluster is still predicted to be the hardest to epenthesise into, RF is now predicted to be more resistant to epenthesis than NT. In addition, of the three clusters with a single downstep in sonority (FT, NF and RN), RN is predicted to be the *least* likely to undergo epenthesis.

Lastly, there are the predictions of the markedness-based analysis. The original Syllable Contact Law is stated as follows:

(10)   Syllable Contact Law: "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 & Vennemann, 1983)

Within Optimality Theory, Syllable Contact has been interpreted as both a categorical constraint (Rose, 2000) and as a gradient family of constraints (Gouskova, 2002, 2004). Gouskova defines the distance DIS between two consonants in a syllable contact situation as the sonority of the second minus the sonority of the first and a universal hierarchy of *DIS-n constraints, where *DIS-$n + 1 \gg$ *DIS-n. This results in heterosyllabic clusters that rise sharply in sonority – that have a high DIS – being more marked than more falling clusters. The precise predicted hierarchy of markedness of the clusters is as follows:

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

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

-3   -2   -1   0   1   2   3   DIS

The DIS metric makes no distinction between clusters of a given sonority distance. Thus, RN, NF and FT are all predicted to be equally marked and equally likely to undergo epenthesis, while RF should be as marked as NT and more marked than RT.

3

3   Case Study: Irish

Irish epenthesis 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.[1]

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).

(12)   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))

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

(13)   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))

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

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

This constraint does not duplicate the work of the IDENT(SON∡)<n constraints, but eliminates the obstruent-initial clusters from consideration, as these are not targeted for epenthesis by any high-ranking constraints.

(15)   *SON-C ≫ DEP

Input: /gorm/	*SON-C	DEP
a. ☞ gorəm		*
b. gorm	*!	

Epenthesis is allowed when C_1 is "followed by a voiced stop, fricative, nasal or liquid, but not when it is followed by a voiceless stop." (Carnie, 1994)

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[1]   This presentation of Irish epenthesis omits details irrelevant to the sonority-driven aspect of the analysis. In particular, word-initial sonorant-initial clusters do not undergo epenthesis, and neither do homorganic clusters.

The varying behaviour of voiced and voiceless stops requires a revision of the standard sonority scale. There is substantial phonological evidence that voiced stops have higher sonority than voiceless ones, e.g. (Dell & Elmedlaoui, 1985; Steriade, 1982). I therefore make the minimal possible revision to the sonority scale by giving voiced stops D the intermediate value of 1.5:

(16)

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

Adding the RD and ND clusters, we have the following SONORITY ANGLE hierarchy for the sonorant-initial clusters of Irish.

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

0.46		1.11	1.25		1.89	2.03	2.21	2.23	2.30	2.36
										RT
NR		RR	NN		RN	NF	RF	ND	RD	NT

2.33
SONORITY ANGLE

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:

(18)   IDENT(SON∡)<2.33 ≫ *SON-C

Input: /kork/	IDENT(SON∡)<2.33	*SON-C
a. ☞ kork		*
b. korək	2.36 *!	
Input: /albə/	IDENT(SON∡)<2.33	*SON-C
c. ☞ aləbə	2.29	
d. albə		*!

3.3 *Comparison to other approaches*   Pursuing a similar analysis based on SONORITY RISE (Flemming, 2008), we see that the clusters RF and RD fall between RT and NT on the relevant portion of the SONORITY RISE cluster hierarchy.

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

0.67	1.0	1.33	1.5	1.67	2.0	2.25	2.5
	RR		RN				
NR	NN	NF	ND	(NT)	RF	RD	(RT)

SONRISE

As a result, we cannot separate the clusters that undergo epenthesis from the ones that do not if we adopt SONORITY RISE as the relevant metric, as we can when we use SONORITY ANGLE (c.f. (17)). This is due in large part to the property of the metric observed earlier, that among clusters with the same downstep in sonority, the least sonorous one will have the smallest SONORITY RISE.

Attempting to construct a markedness-based analysis for the Irish data, we run into several difficulties. The first is to have markedness constraints such as Syllable Contact and Sonority Sequencing apply only to sonorant-initial clusters, when obstruent-initial clusters, which should be even more marked, remain untouched. Second, we need to invoke two different constraints based on syllabic context – Syllable Contact and Sonority Sequencing – and have them coincidentally ranked at identical positions with respect to the faithfulness constraint DEP. This was not necessary under the sonority contour faithfulness analysis.

Suppose then that we extend the definition of *DIS-*n* (Gouskova, 2002) from the heterosyllabic environment alone to all clusters regardless of syllabic position. We expect the following markedness hierarchy of sonorant-initial clusters.

(20)   DIS values of sonorant-initial clusters using the revised sonority scale

-1	0	1	1.5	2	2.5	3
				RF		
	RR	RN				
NR	NN	NF	ND	(NT)	RD	(RT)

$\longrightarrow$ DIS
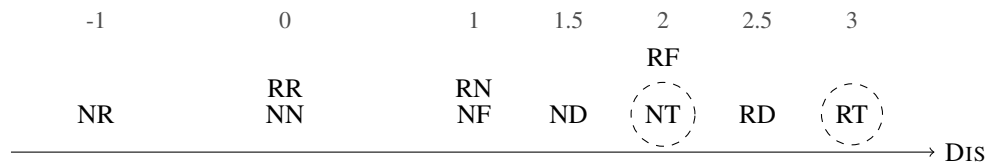
Even ignoring the problem of the obstruent-initial clusters, we see that sonority distance cannot get us the desired result. Instead, it incorrectly predicts that if NT and RT are not broken up by epenthesis, then RF and RD should not either.

I have not considered here other possible interpretations of the Irish data. Taken in isolation, the cut-off at 2.33 may appear arbitrary. In the context of the analysis of Chaha epenthesis presented in the next section, however, Irish epenthesis reinforces a pattern that emerges more forcefully from Chaha: the sets of clusters that do and do not undergo epenthesis can be separated by SONORITY ANGLE.

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 (6), 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). I will specify its sonority as an intermediate 3.5, under the sonority of 4 for liquids in general.

4.1   *Coda clusters*

4.1.1   *Data*   Coda clusters in Chaha are broken up by epenthesis if they are of level or rising sonority. In some idiolects, epenthesis is blocked in obstruent-obstruent clusters. Most falling sonority clusters do not undergo epenthesis, except [r]-sonorant clusters, which can undergo epenthesis in some idiolects. The following table summarises the data.

(21)   Table showing epenthesis patterns for clusters of varying sonority patterns:[2] (Rose, 2000:404–7)

C₁ \ C₂	Stop	Fricative	Nasal	Liquid
Stop	**OPTIONAL** nɨg(ɨ)d	**OPTIONAL** dɨg(ɨ)s	✓ nɨkɨm	✓ gɨdɨr
Fricative	✗ kɨft	**OPTIONAL** mes(ɨ)x	✓	✓ sifɨr
Nasal	✗ gɨnd	✗ tɨmx	✓ gənɨm	✓
Liquid	✗ fɨrt	✗ tɨrx	**OPTIONAL** kɨr(ɨ)m	✓ sɨβɨr

_____

[2]   No specific examples are available in (Rose, 2000) for the gaps in the table, but their pattern of epenthesis is implied in the text and Rose's analysis.

4.1.2 *Analysis* Epenthesis is triggered in coda clusters by the familiar constraint *COMPLEXCODA, but blocked in falling sonority clusters by IDENT(SON∡)<1.5.[3]

(22) IDENT(SON∡)<1.5 ≫ *COMPLEXCODA

Input: /ktf/	IDENT(SON∡)<1.5	*COMPLEXCODA
a. kɨtf		*!
b. ☞ kɨtif	0.59	

Input: /krm/	IDENT(SON∡)<1.5	*COMPLEXCODA
c. ☞ kɨrm		*
d. kɨrim	1.89 *!	

The variable epenthesis behaviour of obstruent-obstruent clusters cannot be reduced to the SONORITY ANGLE hierarchy. Reviewing (7), we see that TF, FF and TT are not a contiguous block in the hierarchy. Rather, it seems that there is a separate dimension of perceptual similarity relevant to vowel epenthesis, which forbids introducing a sonorant region between two obstruents. This has been suggested by Flemming (2008) based on patterns of epenthesis in languages such as Montana Salish, where epenthesis is only licensed adjacent to a sonorant. We can formalise this restriction with the following constraint:

(23) DEP(+sonorant): do not insert a sonorant region between two obstruents.

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 is shared between the vowel and the sonorant.

In those idiolects that forbid obstruent-obstruent epenthesis, therefore, DEP(+sonorant) is ranked above *COMPLEXCODA.

(24) Ranking in one idiolect that forbids obstruent-obstruent epenthesis

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

The last element to be accounted for is those idiolects in which /RN/ groups with the rising and level sonority clusters in undergoing epenthesis despite being of falling sonority. This is accomplished by moving the placement of *COMPLEXCODA from above IDENT(SON∡)<1.5 to above IDENT(SON∡)<1.9, permitting epenthesis in the RN clusters.

(25) IDENT(SON∡)<1.9 ≫ *COMPLEXCODA

| Input: /krm/	IDENT(SON∡)<1.9	*COMPLEXCODA
a. kɨrm		*!
b. ☞ kɨrɨm	1.89	

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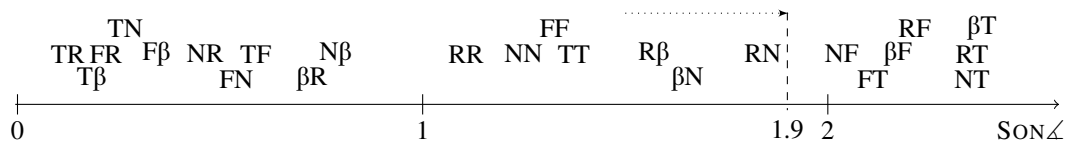
[3] This approach does make one incorrect prediction: that /βm/ should not undergo epenthesis, as its SONORITY ANGLE is 1.65. But it does, as in /səβ-m/ → səβim 'people-EMPH' (Rose, 2000:fn. 16). I suggest that its obligatory epenthesis may be due to a constraint such as OCP(labial).

4.1.3 *Comparison to other approaches* SONORITY RISE (Flemming, 2008) can explain those idiolects 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 the idiolects that permit epenthesis into /RN/. 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 do so, but FT never does.

(26)   No linear separation between the rising and level sonority clusters plus RN from the rest of the falling sonority clusters under the SONORITY RISE metric.
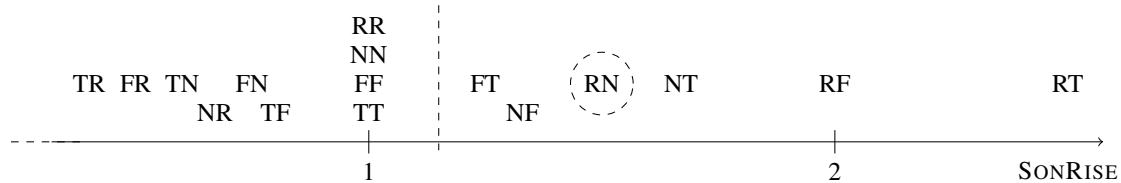
Rose (2000) offers an explanation for these facts in terms of Sonority Sequencing (Selkirk, 1984). However, this alone cannot explain the behaviour of RN versus the remaining falling sonority clusters, as neither the categorical formulation of Sonority Sequencing that Rose employs, nor a family of *DIS-*n* constraints, naturally allows this division.

(27)   No linear separation between the rising and level sonority clusters plus RN from the rest of the falling sonority clusters under the DIS metric.
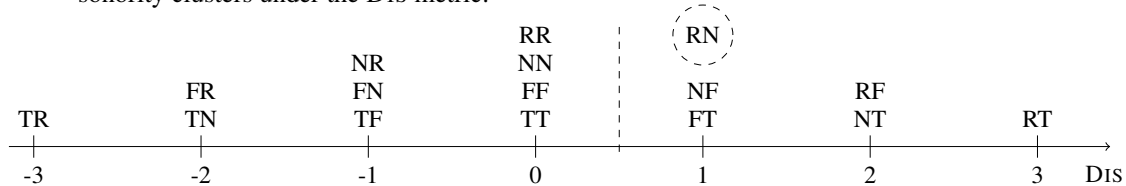
Therefore, Rose needs to invoke the following constraint to cause epenthesis in these clusters:

(28)   *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:

(29)   *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]. On the other hand, the sonority contour faithfulness approach does not have to single out [r] for special treatment 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, albeit at the expense of requiring a constraint against [βm] clusters (see footnote 3).

4.2 *Triconsonantal clusters* Triconsonantal clusters in Chaha are found in 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/. These are always broken up as [CCɨC] or [CɨCC].

As with coda clusters, there is considerable inter- and intra-speaker variability in epenthetic positioning.

4.2.1 *Data and Analysis* Triconsonantal clusters must be broken up via epenthesis. I attribute this to the action of undominated *CCC, which outranks DEP. I employ this constraint against three consecutive consonants rather than *COMPLEXCODA as we have seen that *COMPLEXCODA is sometimes violated, whereas *CCC is always satisfied by epenthesis between either C_1-C_2 or C_2-C_3. We do not need a separate constraint to prevent double epenthesis occurring to produce *[CɨCɨC], as this form will never be more harmonic than the ones with single epenthesis.

(30)   *CCC $\gg$ DEP

Input: /CCC/		*CCC	DEP
a.	CCC	*!	
b. ☞	CCᵻC		*
c. ☞	CᵻCC		*
d.	CᵻCᵻC		**!

This holds for all the "idiolects" reported in Rose (2000). Within each, we need only explain the location of epenthesis. The idiolects enumerated in Rose are the following:

(31)   a.   The "default idiolect", discussed in Section 4.3 of Rose (2000).
                  (i)   [CᵻCC] if C_1C_2 is a rise or plateau and C_2C_3 is a fall.
                  (ii)   [CCᵻC] otherwise.
          b.   [CRᵻN] idiolect, discussed in Section 5.2.2 of Rose (2000).
                  (i)   [CCᵻC] if C_2 is [r] and C_3 is a sonorant.
                  (ii)   Otherwise as default.
          c.   [CᵻCC] idiolect, discussed in Section 5.2.1 of Rose (2000).
                  (i)   [CCᵻC] if C_2C_3 is a fall and C_1C_2 is a rise or plateau.
                  (ii)   [CᵻCC] otherwise.
          d.   [wᵻzf, sᵻgd] idiolect, discussed in Section 5.2.1 of Rose (2000).
                  (i)   In this idiolect alone, /wzf/ and /sgd/ epenthesise as [wᵻzf] and [sᵻgd].

Since the size of the SONORITY ANGLE between C_1-C_2 versus C_2-C_3 is not the sole arbiter of epenthesis position, I conjecture, following Rose (2000), that each idiolect has some alignment preference. To capture this, I borrow two constraints from Rose's analysis:

(32)   a.   ALIGN-LEFT: every consonant must be aligned with the left edge of some prosodic word. (Rose, 2000:(21))
          b.   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))

Each of these favours one or the other of the two possible outcomes for the /jə-CCC-o/ forms.

(33)   ALIGN-LEFT favours epenthesis on the right as [CCᵻC], while ANCHOR-LEFT ROOT favours [CᵻCC] for the 3rd person jussive triliteral verbal forms.

Input: /j-CCC-o/		ALIGN-LEFT	ANCHOR-LEFT ROOT
a.	jə-CCᵻC-o	2,3,5	*!
b.	jə-CᵻCC-o	2,4!,5	

DEP(+sonorant) does not appear to override these preferences in any of the idiolects. I assume it is outranked by ALIGN-LEFT and ANCHOR-LEFT ROOT and thereby inactive in the analysis of CCC clusters.

    If ALIGN-LEFT dominates ANCHOR-LEFT ROOT, then the default epenthesis site will be on the right, yielding [CCᵻC]. However, this can be overridden by a dominating IDENT(SON∡)<n constraint — if SON∡(C_2,C_3) is larger and SON∡(C_1,C_2) smaller than the threshold n, then epenthesis will occur on the left instead, yielding [CᵻCC]. This is what we see in the first two of the four idiolects.

(34)   /CCC/ behaviour in idiolect (31-a). Underlined forms show variation in other idiolects.[4] (Rose, 2000:(24,26,28,30,32))

	Underlying form	Surface form	$\text{SON}\angle(C_1,C_2)$	$\text{SON}\angle(C_2,C_3)$
	Fall-{Rise, Plateau}: [CCiC]			
a.	jə-<u>wzf</u>-o	jəwzifo	2.03	1.33
b.	jə-mxr-o	jəmxiro	2.03	0.22
c.	jə-<u>sgd</u>-o	jəsgido	2.11	1.37
d.	jə-<u>sdβ</u>-o	jəsdiβo	2.11	0.18
	{Rise, Plateau}-{Rise, Plateau}: [CCiC]			
e.	jə-<u>gdf</u>-o	jəgdifo	1.37	0.59
f.	jə-<u>gdr</u>-o	jəgdiro	1.37	0.12
g.	jə-<u>kmr</u>-o	jəkmiro	0.27	0.46
h.	jə-<u>sfr</u>-o	jəsfiro	1.33	0.22
i.	jə-<u>sβr</u>-o	jəsβiro	0.34	0.73
	Fall-Fall: [CCiC]			
j.	j-a-<u>mst</u>-o	jamsito	2.03	2.11
	{Rise,Plateau}-Fall: [CiCC]			
k.	jə-<u>k'rm</u>-o	jək'irmo	0.12	1.89
l.	jə-<u>srβ</u>-o	jəsirβo	0.22	1.57
m.	jə-drs-o	jədirso	0.12	2.21
n.	jə-kft-o	jəkifto	0.59	2.11
o.	jə-dmd-o	jədimdo	0.27	2.36
p.	jə-frt-o	jəfirto	0.22	2.36
q.	jə-sβx-o	jəsiβxo	0.34	2.17
r.	j-a-mrg-o	jamirgo	0.46	2.36

In these forms, epenthesis is always on the right unless the C_2-C_3 SONORITY ANGLE exceeds 1.5:

(35)   IDENT(SON∠)<1.5 ≫ ALIGN-LEFT

     a.   Fall-{Rise, Plateau}

Input: /jə-wzf-o/	IDENT(SON∠)<1.5	ALIGN-LEFT
a. ☞ jəwzifo	1.33	
b. jəwizfo	2.03 ∗!	∗

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

Input: /jə-gdf-o/	IDENT(SON∠)<1.5	ALIGN-LEFT
c. ☞ jəgdifo	1.37	
d. jəgidfo	0.59	∗!

     c.   Fall-Fall

Input: /j-a-mst-o/	IDENT(SON∠)<1.5	ALIGN-LEFT
e. ☞ jamsito	2.11 ∗	
f. jamisto	2.03 ∗	∗!

     d.   {Rise, Plateau}-Fall

Input: /jə-kft-o/	IDENT(SON∠)<1.5	ALIGN-LEFT
g. jəkfito	2.11 ∗!	
h. ☞ jəkifto	0.59	∗

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[4]   According to Rose, (34j) does not show variation. However, at least one native speaker of Chaha can produce [jamisto] (Degif Petros Banksira, p.c.). Forms with an initial /r/ or /n/ are omitted, as these obligatorily epenthesise as [jəCCiCo] due to a morphophonological alignment constraint on jussive forms (Rose, 2000; Banksira, 2000; Taranto, 2001).

A further note on the fall-fall case is necessary. Notice that in breaking up /mst/ as [msɨt], the larger SONORITY ANGLE cost of 2.11 was incurred. Looking at the tableau in (35-c) above, this seems to be the expected behaviour. However, this depends on the placement of the other IDENT(SON∡)<n constraints. This constraint family forms a stringency hierarchy in that any candidate that violates IDENT(SON∡)<n, also violates all IDENT(SON∡)<m where $m < n$. There has been some debate in the literature as to whether constraints in stringency hierarchies should be fixed in a universal ranking with the least stringent constraint the highest ranked (Prince & Smolensky, 2003), or allowed to be freely ranked (de Lacy, 2004), so that a more stringent constraint may outrank a less stringent one.

If we adopt the universal ranking position, then we cannot straightforwardly derive [jamsɨto]:

(36)   Universal ranking cannot derive [jamsɨto]

Input: /j-a-mst-o/	IDENT(SON∡)<2.1	IDENT(SON∡)<1.5	ALIGN-LEFT
a. ☺ jamsɨto	2.11 ∗!	2.11 ∗	
b. ☞ jamɨsto	2.03	2.03 ∗	∗

Rather, we require conflation on both sides of the markedness constraint — the degree to which the SONORITY ANGLE exceeds 1.5, or is under 1.5, does not matter. This requires a flexible ranking of the IDENT(SON∡)<n family of constraints. For simplicity, I will assume that all IDENT(SON∡)<n constraints, other than the crucial one ranking above markedness, are ranked so low as to be inactive.

Looking at the four idiolects, we find that they all involve faithfulness conflation of clusters that can be grouped by SONORITY ANGLE, and thus the epenthetic behaviour of all four idiolects can be explained by ranking an IDENT(SON∡)<n constraint above the relevant alignment constraint.

(37)   a.   Idiolect 1 (sonority rises and plateaus) vs (sonority falls)
         b.   Idiolect 2 : (sonority rises and plateaus and RN) vs (other sonority falls)
         c.   Idiolect 3 : (sonority rises and plateaus) vs (sonority falls)
         d.   Idiolect 4 : (sonority rises) vs (sonority plateaus and falls)
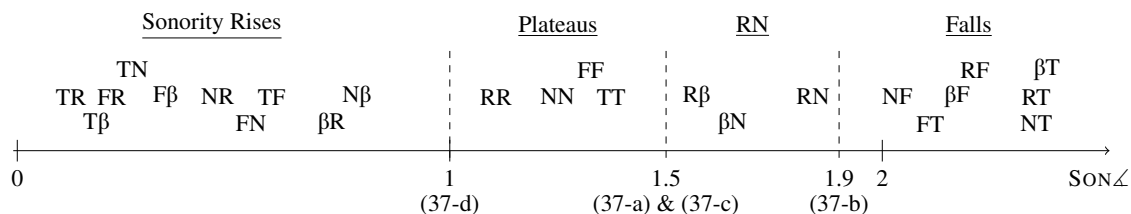
4.2.2 *Comparison with other approaches*   The SONORITY RISE metric can achieve the same linear separation for idiolects (37-a), (37-c) and (37-d), but notice that this is not possible for idiolect (37-b):

(38)   SONORITY RISE cannot achieve a linear separation of the sonority rises, plateaus and RN from the remainder of the falling sonority clusters.
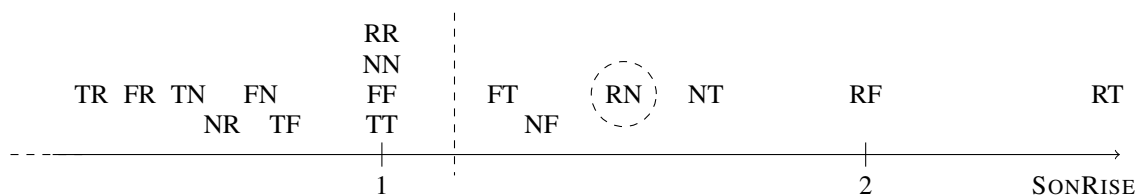
Rose (2000) presents a successful analysis of the same data in Chaha, from which I have liberally borrowed. Under her approach, it is Syllable Contact that triggers epenthesis. To this end, she employs two versions of Syllable Contact that achieve the grouping effect above. The first penalises sonority rises and plateaus, while the second, looser, constraint, penalises only rises. The variable behaviour of the /CRN/ clusters is modelled using the *R-SON constraint from her analysis of coda clusters.

In addition to these, however, Rose requires a constraint that limits the action of Syllable Contact, as not all clusters violating Syllable Contact are broken up by epenthesis. If both clusters in a triconsonantal cluster

are sonority rises, only a single epenthetic vowel is inserted. In addition, medial two-consonant clusters that violate Syllable Contact are never broken up by epenthesis. The constraint Rose uses is *MEDIALLIGHT, which penalises the output configuration [V.Cɨ.CV]. This constraint is unnecessary under the sonority contour faithfulness approach, as double epenthesis does not satisfy *CCC any better than epenthesis at a single site.

Rose's analysis of the triconsonantal clusters carries over directly to epenthesis positioning in quadriconsonantal clusters. While there is insufficient space to present it, I will note that the SONORITY ANGLE-based analysis of /CCC/ clusters presented above also translates to the /CCCC/ clusters without modification of the rankings, and correctly predicts epenthesis positioning in all clusters save one.

5   Conclusion

In this paper, I argued for sonority contour faithfulness being the right way to analyse sonority-driven epenthesis. I additionally proposed that sonority contour faithfulness should be computed by a metric like SONORITY ANGLE, which has two qualities that have been shown to be desirable for such a metric: (i) the more positive the gradient of the sonority contour from C_1 to C_2, the smaller the faithfulness cost, and (ii) the more sonorous C_1 and C_2 are, the smaller the faithfulness cost. Two empirical predictions of SONORITY ANGLE, (i) that RT and NT should be the least susceptible to epenthesis of all clusters, and (ii) that RN is the most susceptible to epenthesis of the falling sonority clusters, allowed us to simplify the analyses of Irish and Chaha significantly by ranking a single IDENT(SON∡)<n constraint against a relevant markedness constraint.

Any metric, however, has certain assumptions built in. For instance, I assumed that the horizontal distance covered by each contour was of 1 unit, and that the major sonority classes are equally spaced on a sonority scale, which is unlikely to be true under an acoustic interpretation of sonority (Parker, 2002). Changes to these assumptions may result in different cluster hierarchies. Therefore, further work needs to be done to verify the predictions of SONORITY ANGLE, through perceptual experiments and further empirical cross-linguistic investigation of sonority-driven phenomena.

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