Vowel reduction is conditioned by quality and quantity interactions: Evidence from Bolognese

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Abstract. This study presents the first formal analysis of vowel reduction in Bolognese, a Gallo-Italic language spoken in Bologna, Italy. While vowel reduction in many languages is predictable from place features alone, Bolognese shows length-sensitive asymmetries: front-mid vowels reduce differently depending on whether they are underlyingly short or long. I propose a sonority-based analysis in Optimality Theory, where both vowel height and length contribute to a vowel's total sonority. Sonority is then evaluated by a new faithfulness constraint, Maintain(sonority), which penalizes changes of sonority on input-output correspondence. In the analysis, vowels above a certain sonority threshold reduce to [a], while those below reduce to [i], illustrating how grammars can demonstrate sensitivity to multiple independent contributors of sonority, and how pressures to reduce sonority and maximize contrast can interact to determine vowel reduction.

Keywords. phonology; optimality theory; vowel reduction; sonority; scalar faithfulness constraints; Gallo-Italic languages; Bolognese

1. Introduction. The vowel system of Bolognese (Gallo-Italic; Italy) presents a theoretical problem for constraint-based models of vowel reduction. Unlike the many patterns discussed by Crosswhite (1999), reduction in Bolognese exhibits two patterns, depending on input vowel length: short front mid vowels (/e, ɛ/) reduce to the high vowel [i], whereas their long counterparts (/eː, ɛː/) reduce instead to the low vowel [a]. These reduction patterns are individually attested cross-linguistically, yet no existing analysis derives both patterns within a single grammar. The result is a dual pattern paradox: how can one system simultaneously enforce two contradictory patterns on the same vowels, each triggered in the same prosodic environment, differentiated only by input vowel length?

This paper argues that the solution lies in recognizing that quality and quantity contribute independently to a segment's total sonority, and that grammars can evaluate the relationship between input and output segments with regard to sonority. Building on previous proposals that sonority may arise from multiple phonetic factors, I develop an analysis in which the grammar is sensitive to the combined sonority contributions from vowel height and length. I propose a new scalar faithfulness constraint, Maintain(sonority), which penalizes changes in the total sonority of a segment between the input and output. When ranked alongside other constraints governing unstressed vowels, Maintain(sonority) predicts the observed split: short mid vowels, relatively low in total sonority, minimize sonority change by reducing to [i], while long

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mid vowels, whose length increases their total sonority, minimize change by reducing to [a], a more sonorous peripheral vowel.

The remainder of this paper proceeds as follows: I begin by presenting the Bolognese vowel reduction patterns (§2) and introduce my proposal in which a new scalar faithfulness constraint MAINTAIN(SONORITY) enforces restrictions on the sonority difference between input and output correspondents (§3). After presenting the analysis, I discuss Nanti stress assignment, which provides evidence that vowel quality and quantity contribute separately to total sonority (§4). I then briefly consider alternative frameworks, showing why they fail to derive the pattern (§5). Finally, I outline remaining questions concerning vowel deletion and describe the next steps in extending the analysis (§6).

2. Bolognese vowel reduction. Bolognese has seven contrastive vowel qualities: /i, e, ɛ, a, ɔ, o, u/. Vowel reduction occurs when primary stress shifts[1] due to suffixation,[2] as shown in (1) and (2). Because unstressed mid vowels surface in positions where their stress assignment remains consistent (/o/ & /e/ in (1a) and (1b)), but not when it changes due to suffixation (/ɔ/ → [u] in (1b)), vowel reduction only occurs on the newly unstressed vowel.

(1) a. koperˈtɔŋ
‘vehicle tire; inedible steak’
b. kopertuŋ ˈθ -eŋ
‘small vehicle tire; small inedible steak’

The data in this paper is sourced from the Italian-Bolognese dictionary (Lepri & Vitali 2009) and the pedagogical grammar of Bolognese (Vitali 2009, 2022), with IPA transcriptions based on the phonetic description of the orthography as described in these works.

Because mid vowels do not surface in the context for vowel reduction,[3] as seen in (2), this is analyzed as an effect of prominence-based licensing, where “non-peripheral” vowels are licensed (i.e., permitted) only in stressed positions (Walker 2011).

(2)	*plain*	*suffixed*	*gloss*
	maˈneːs-a	maniˈs-eŋna	‘wrench’
	ˈlɛŋgw-a	liŋˈgw-eŋna	‘language’
	kaˈvast-er	kavasˈtr-eŋ	‘tool’
	gabˈjɔŋ	gabjuŋˈθ-eŋ	‘gabion’

The distinction between “peripheral” and “non-peripheral” vowels must be made for the successful analysis of vowel reduction in the language, as “peripheral” vowels never undergo a change in quality as a result of reduction. Here, “peripheral” vowels are those that are maximally dispersed from one another in the vowel space, shown in red in Figure 1. That is, the high-front /i/, the high-back /u/, and the low-central /a/. “Non-peripheral” vowels refer to the mid vowels, shown in black in Figure 1. That is, the [-HIGH, -LOW] unrounded vowels /e/ and /ɛ/, and the [-HIGH, -LOW] round vowels /o/ and /ɔ/.

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[1] See Jones (2024) for an overview of Bolognese stress.

[2] In Osgan (in prep.), this is categorized as a morphologically derived environment effect (MDEE).

[3] Occasional occurrences of long mid vowels shortening are also observed in the data collected. In Osgan (in prep.), this is analyzed as an effect of high input activity using Gradient Harmonic Grammar (Smolensky & Goldrick 2016; Hsu 2022).

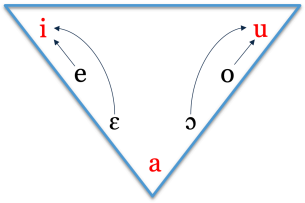

Figure 1. Bolognese vowel inventory with short vowel reduction targets

Bolognese has contrastive vowel length in stressed syllables, with both long and short vowels participating in vowel reduction. Underlying short non-peripheral vowels (mid vowels) reduce to the high vowel with the same [ROUND] specification (indicated with arrows in Figure 1).[4]

In an Optimality Theory analysis (Prince & Smolensky 1993/2004), this restriction against non-peripheral vowels is enforced by a markedness constraint LICENSE NON-PERIPHERAL/STRESS (Crosswhite 1999).

(3) LICENSE NON-PERIPHERAL/STRESS
Assign one violation for each non-peripheral vowel in an unstressed position.

In Tableaux (4), the ranking of LICENSE NON-PERIPHERAL/STRESS (abbreviated in some tableaux as LNP) above a faithfulness constraint against changes in vowel quality prevents the mid vowel from surfacing.

(4)

/spepˈl-eɲna/	LICENSE NON-PERIPHERAL	FAITH
a. [spepˈl-eɲna]	*! W	L
☞ b. [spipˈl-ɲna]		*

While stressed syllables can contain a long vowel, outputs of vowel reduction are always short. It is here that we observe the theoretically noteworthy pattern investigated in this paper. While most lengthened input qualities reduce to the same peripheral vowel as their short counterpart, the front mid vowels /e/ and /ɛ/, when long, reduce to the low peripheral vowel [a], while when short, they reduce to the high peripheral vowel [i].

(5)

plain	*suffixed*	*gloss*
sarˈvesːi	sarviˈsj-eɲ	‘service’
laɲˈteːrn-a	laɲtarˈn-eɲna	‘lantern’
ˈdɛɲt	diɲˈt-eɲ	‘tooth’
ˈgɛːbj-a	gabˈj-eɲna	‘cage’

The reduction pattern for short vowels, where front mid vowels raise to [i], is attested cross-linguistically (Harris 1998), as is the long vowel pattern, where they lower to [a] (Recasens 1991). However, both patterns cannot be generated within a single grammar when analyzed using only IDENT[F] constraints in Optimality Theory.

2.1. THE DUAL PATTERN PROBLEM. Restrictions on the featural faithfulness of output candidates are often imposed via the IDENT[F] constraint family[5] (McCarthy & Prince 1995) and

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[4] Although the three-way lax contrast /ɛ, a, ɔ/ appears to likely have collapsed to something like [a] for younger speakers (Canepari & Vitali 1995), the distinction is maintained in vowel reduction.

follow the definition in (6).

(6) Ident[F]
Assign one violation for every output segment whose specification of the feature *F* differs from that of its input correspondent.

In Bolognese vowel reduction, the relevant features that interact with reduction are height and roundness. The constraint Ident[Round] serves to maintain faithfulness to the feature [Round] between the input and the output vowel, while Ident[Low] and Ident[High] serve to maintain faithfulness to the features [Low] and [High], respectively. The ranking of License Non-Peripheral/Stress ≫ Ident[High] in Tableaux (7) and (8) ensures that mid vowels raise to a high peripheral vowel.

(7)

/gardleˈn-eŋ/	Ident[Rnd]	LNP	Ident[Low]	Ident[High]
a. [gardleˈn-eŋ]		*! W		L
☞ b. [gardliˈn-eŋ]				*
c. [gardluˈn-eŋ]	*! W			*
d. [gardlaˈn-eŋ]			*! W	L

(8)

/pɔndˈg-eŋ/	Ident[Rnd]	LNP	Ident[Low]	Ident[High]
a. [pɔndˈg-eŋ]		*! W		L
b. [pindˈg-eŋ]	*! W			*
☞ c. [pundˈg-eŋ]				*
d. [pandˈg-eŋ]	*! W		* W	L

Recall from the data in (5) that the front mid vowels /e/ and /ɛ/ differ in which peripheral vowel they reduce to contingent on their input length. Although both patterns can be generated using the constraints presented above, these patterns cannot be simultaneously generated in a single grammar, as occurs in Bolognese. The constraint Ident[Low] must outrank Ident[High] to derive the pattern in which front mid vowels reduce to [i], while the reverse is necessary to derive the pattern in which long front mid vowels reduce to [a].

(9)

/bɛːrˈb-eŋna/	Ident[Rnd]	LNP	Ident[Low]	Ident[High]
a. [bɛːrˈb-eŋna]		*! W	L	
💣 b. [birˈb-eŋna]			L	* W
☞ c. [barˈb-eŋna]			*	
d. [burˈb-eŋna]	*! W		L	* W

(10)

/prɛnθiˈp-eŋ/	Ident[Rnd]	LNP	Ident[Low]	Ident[High]
a. [prɛnθiˈp-eŋ]		*! W		L
☞ b. [prinθiˈp-eŋ]				*
c. [pranθiˈp-eŋŋ]			*! W	L
d. [prunθiˈp-eŋ]	*! W			L

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[5] Similarly, some works instead adopt the further segmented Max[F] & Dep[F] family of constraints (Zoll 1996; Lombardi 2001). Though their adoption is possible in the analysis presented in this paper, it does not resolve the asymmetry observed between long and short front mid vowels.

While traditional IDENT[F] constraints alone fail to generate the vowel reduction pattern observed in Bolognese, I propose an analysis in which the addition of a new scalar faithfulness constraint MAINTAIN(SONORITY) successfully generates the observed vowel reduction patterns.

3. A sonority-based model. Crosswhite (1999) posits that vowel reduction has two primary motivators: Prominence Reduction and Contrast Enhancement. Prominence-reducing vowel reduction removes highly sonorous qualities from unstressed positions. Common exemplars of this include languages in which low vowels (e.g., [a]) are dispreferred relative to high vowels (e.g., [i, u]). Contrast-enhancing vowel reduction reduces the number of possible qualities in unstressed vowels while increasing their perceptibility with respect to one another. This type of reduction is also known as dispersion-enhancing reduction, as vowels disperse to a minimal inventory of possible qualities while being maximally distinct from one another. (Lindblom 1986).

The presence of the peripheral vowel /a/ is indicative that vowel reduction in Bolognese is also motivated by contrast enhancement rather than strictly prominence reduction, since a highly sonorous quality like /a/ can surface due to its peripheral position. The change in peripheral vowel output for long versus short /e/ and /ɛ/ is thus not only a change in height, but also a change in sonority (Ladefoged 1971; Parker 2002, 2008); reduction to the high peripheral vowel leaves a minimally sonorous segment in an unstressed position, while reduction to the low peripheral vowel leaves a more sonorous segment.

Restrictions on adjacent segments in terms of their relative sonority are well established (Ladefoged 1971; Clements 1990; Zec 1995; Parker 2002; Cser 2012; Krämer & Zec 2020; among others). Notably, this includes the SONORITY SEQUENCING PRINCIPLE, which states that sonority must decrease along the sonority hierarchy as the position of a segment moves away from the nucleus of the syllable, and the constraint MAXIMUM SONORITY DISTANCE, which restricts the distance between sonority levels that adjacent segments can exhibit. Under this notion that grammars are sensitive to the distance and directional changes in sonority between adjacent segments, I propose that grammars can likewise be sensitive to input-output correspondence in this dimension, such that output segments are restricted in the change of their total sonority value between the input and output. The constraint that evaluates this movement, I call MAINTAIN(SONORITY). This type of constraint penalizes movement along a scalar dimension (here: sonority). It is similar to the scalar IDENT-ADJACENT constraint proposed by Gnanadesikan (1997) in that a hierarchical scale is evaluated rather than a binary feature, but differs in that it can be applied to scales with more than three values, the maximum assumed by Gnanadesikan's ternary feature system. Unlike IDENT constraints, which receive a single violation for any change of a feature *F*, MAINTAIN constraints are violated by each movement along a scale *X*, such that greater changes in sonority are more penalized.

(11) a. MAINTAIN(X-SCALE)
Assign *N* violations for every output segment that differs in value of the defined scale *X* from its input correspondent, where *N* is the absolute value difference between the input and output values of the defined scale *X*.

b. MAINTAIN(SONORITY)
Assign *N* violations for every output segment that differs in total sonority from its input correspondent, where *N* is the absolute value difference between the input and

output sonority values.

3.1. CALCULATING SONORITY FROM HEIGHT AND LENGTH. I also propose that multiple phonetic factors can contribute to a segment's overall sonority (Parker 2002; Gordon et al. 2012). Specifically, I argue here that a segment's length contributes to its overall sonority independently of its quality. A well-known correlate of a vowel's sonority is its height, where lower height equates to higher sonority. To implement this continuum, I employ a numerical scale, where a greater value corresponds to greater sonority.

Height	Vowel	Total Sonority Value
high	/i, u/	1
mid	/e, o, ɛ, ɔ/	2
low	/a/	3

Table 1. Relative sonority values by vowel height

In languages that have contrastive vowel length, long vowels are proposed to have two morae (μ) associated with one vowel node (McCarthy & Prince 2001; Zec 1989, 2007). This notion of moraic theory can be extended to our model of sonority, such that an increase in morae results in an increase in overall sonority level. Following the numerical scale in Table 1, the sonority level of a long vowel is calculated as the sum of the value assigned by quality for each assigned mora. That is, each mora of a long vowel receives an amount of sonority determined by the vowel's height. For example, if the sonority value associated with high vowels like /i/ is 1, the lengthening of the vowel results in an overall sonority value of 2. Likewise, if the sonority value of mid vowels like /e/ is 2, then long mid vowels like /eː/ have an overall sonority value of 4. This interaction between sonority and vowel quality and quantity predicts grammars in which minimally sonorous long vowels (i.e., non-low vowels) pattern with highly sonorous short vowels (i.e., low vowels like /a/), just as is observed in Bolognese vowel reduction.

3.2. ANALYSIS. The MAINTAIN(SONORITY) constraint presented in (§3) enforces a preference for vowels to change minimally in total sonority from input to output. Recall that short [i], [u] and [a] are the only outputs of vowel reduction in Bolognese, and that vowel reduction is always sonority reducing. While the vowel sonority hierarchy itself remains invariant, the increased total sonority level of long vowels allows for the grouping of vowel inputs into thresholds based on how they pattern in the language. The sonority thresholds of vowels in Bolognese is shown in Figure 2.

/i, u/ $\prec$ /iː, uː, e, o, ɛ, ɔ/ $\prec$ /a/ $\prec$ /eː, oː, ɛː, ɔː, aː/

Figure 2. Bolognese vowel sonority thresholds[6]

The restriction against long vowels in unstressed syllables is enforced by the WEIGHT-TO-STRESS PRINCIPLE (Prince 1990), a markedness constraint that assigns a violation to any candidate with an unstressed long vowel. Because the WSP is never violated by the winning candidate, it is undominated in the ranking.

The vowel reduction pattern in Bolognese is generated by the constraint ranking in (12).

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[6] Following the numerical scale proposed in Table 1, the choice to concatenate the /aː/ (with a total sonority level of 6) with the previous sonority threshold /eː, oː, ɛː, ɔː/ (with a total sonority level of 4) is done to simplify violations, as reduction of /aː/ to [a] will always incur less violation of MAINTAIN(SONORITY) than reduction to [i].

Tableaux (13–16) illustrate the individual ranking arguments. By adopting this constraint ranking, the grammar generates outputs in which sonority prominence is minimally reduced to create a maximally dispersed sub-inventory of vowels.

(12) {Ident[Round], LNP} ≫ Maintain(sonority) ≫ Ident[Low] ≫ Ident[High]

In Tableau (13), because candidate *c* incurs a single violation of Ident[Low], but not Ident[High], and vice versa for candidate *b*, Ident[Low] must be ranked above Ident[High] for the grammar to correctly predict the optimal output. It is this ranking between Ident[Low] and Ident[High] that generates the preference of input mid vowels raising to [i] over lowering to [a].

(13)

/pulɛˈt-eŋna/	Ident[Rnd]	LNP	Maint.(son)	Ident[Low]	Ident[High]
a. [pulɛˈt-eŋna]		*! W	L		L
☞ b. [puliˈt-eŋna]			*		*
c. [pulaˈt-eŋna]			*	*! W	L
d. [puluˈt-eŋna]	*! W		*		*

In Tableau (14), the input vowel has the same quality as the vowel in Tableau (13), though importantly, it is long in the input and thus has a greater total sonority value. Because of this, candidate *b* incurs more violations of Maintain(sonority) than candidate *c* (due to the increased sonority difference between /ɛː/ and [i]); thus, candidate *c* is correctly predicted to be the optimal output. Without Maintain(sonority), the grammar would be unable to predict this.

(14)

/kuʧɛːˈr-eŋ/	Ident[Rnd]	LNP	Maint.(son)	Ident[Low]	Ident[High]
a. [kuʧɛːˈr-eŋ]		*! W	L	L	
b. [kuʧiˈr-eŋ]			***! W	L	* W
☞ c. [kuʧaˈr-eŋ]			*	*	
d. [kuʧuˈr-eŋ]	*! W		*** W	L	* W

In Tableau (15), because candidates *b* and *c* incur a violation of the high-ranked constraint Ident[Round], candidate *d* is correctly predicted to be optimal, despite having more violations of Maintain(sonority) than candidate *c*. This shows that, while unranked with respect to one another, Ident[Round] and License Non-Peripheral/Stress must dominate Maintain(sonority).

(15)

/ʧoːdˈl-eŋ/	Ident[Rnd]	LNP	Maint.(son)	Ident[Low]	Ident[High]
a. [ʧoːdˈl-eŋ]		*! W	L		L
b. [ʧidˈl-eŋ]	*! W		***		*
c. [ʧadˈl-eŋ]	*! W		* L	* W	L
☞ d. [ʧudˈl-eŋ]			***		*

In Tableau (16), the fully faithful candidate *a* is already a peripheral vowel, incurring no violations of the licensing constraint. Because changing quality would incur one or more violations of the other faithfulness constraints, the fully faithful underlying form is correctly predicted to be optimal.

(16)

/mudanˈt-eŋ/	Ident[Rnd]	LNP	Maint.(son)	Ident[Low]	Ident[High]
☞ a. [mudanˈt-eŋ]					
b. [mudinˈt-eŋ]			**! W	* W	* W
c. [mudunˈt-eŋ]	*! W		** W	* W	* W

4. Interactions between phonetic contributors of sonority. Just as the claim that multiple phonetic factors can contribute to a segment's overall sonority (Parker 2011; Gordon et al. 2012) is used to explain Bolognese vowel reduction, we observe a similar phenomenon with stress assignment in Nanti, a Kampa language spoken in Peru (Crowhurst & Michael 2005). Nanti prefers iambic stress by default, but allows for trochaic stress given certain combinations of footed vowels. Stress assignment is sensitive to both vowel quality and quantity, where stress is attracted to heavy (bimoraic) syllables over light (monomoraic) syllables (e.g., the first two feet in (17c) and (17d)), but attracted to vowels of lower height when syllables are of equal weight (e.g., the first foot in (17a) and (17b)).

(17) Nanti (Crowhurst & Michael 2005: 53, 55)[7]

a. (à.wo)(te.hái).gʒi].ri
'We approached him/them.'

b. (pi.pò)(ká.kse)].na
'You came to me.'

c. (jo.bìi)(kái.ga).kse]
'They.M drank.'

d. (ja.máa)(ta.kòi)(ga.nà).kse]
'They.M floated it away.'

Though not originally described as such, given the observed interactions between vowel quality and quantity in Bolognese vowel reduction, we can posit that Nanti assigns stress to the most sonorous syllable (i.e., the syllable with the highest prominence, or 'stressability'). Given this, thresholds are predicted to exist in which the optimal outcome cannot be determined if considering quality or quantity alone. In Nanti, this is observed with the stress assignment of the diphthong /ɯi/. When compared with the highly sonorous low vowel /a/, the diphthong is unstressed, as in (18a) and (18c). However, when compared with the moderately sonorous mid vowel /o/, the diphthong has the same 'stressability' as /o/, as seen in (18b) and (18d).

(18) Nanti (Crowhurst & Michael 2005: 53, 54)

a. (jà.mɯi)(ta.kói).ga.kse].na
'They helped us with something else.'

b. (nò.tɯi)(já.kse)].ro
'I knocked it over.'

c. (i.rà)(mɯi.tà)(kói.ga).ksem]pa
'They.M will help someone with something.'

d. (no.tɯí).je].ro
'I will knock it over.'

I claim that the distribution of stress on the diphthong /ɯi/ is a result of its sonority level. That is, because the comprising qualities /ɯ/ and /i/ are both relatively low in sonority (following the sonority continuum given in Table 1, a value of 1), when they are combined to form the diphthong, their combined sonority level[8] (=2) remains less sonorous than the monophthong /a/ (=3),

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[7] The right square bracket (]) marks the right edge of the prosodic word

[8] It is possible to imagine a system in which nuclei are present in the mental lexicon and can therefore be evaluated by the grammar. In such a system, we would posit that total sonority is calculated as the sum of the value assigned by quality for each assigned mora in the nucleus. For example, where the sonority level of /a/ is 3 and the sonority

equally sonorous (and thus equally 'stressable') as the monophthong /o/ (=2), and more sonorous than the monophthong /i/ (=1). While Crowhurst & Michael attribute this divergent behavior of the diphthong /ɯi/ to being exceptionally monomoraic, the proposal in this paper maintains the notion that diphthongs are bimoraic (McCarthy & Prince 2001; Zec 1989, 2007).

Additionally, Crowhurst & Michael claim that /ɯi/ is more 'stressable' than /i/ due to the increased complexity of a single mora branching out to dominate two vowels, yet /ɯi/ and /o/ are analyzed as equally 'stressable.' By employing the same sonority continuum in Table 1 (§3.1), and using the claim that stress is assigned to the most sonorous syllable, the /a/ > /o/, /ɯi/ > /i/ distinction is explained, where the sonority level of /ɯi/ is the sum of the sonority levels of the comprising qualities. Given this, I claim that Nanti stress assignment supports the proposal that quality and quantity can interact to influence the overall sonority of a segment, and that thresholds exist in which combinations of vowel quality and quantity yield equally sonorous segments.

5. Alternatives. There are at least two other approaches that have been used to describe similar phenomena, yet prove unsuccessful at generating the vowel reduction pattern in Bolognese.

5.1. GANG EFFECTS IN HARMONIC GRAMMAR. Similar to Optimality Theory, Harmonic Grammar (Legendre et al. 1990) uses violable constraints; in this framework, however, constraints are assigned a numerical weight. A candidate's harmony (H) score is defined by the following equation in Figure 3:

$$H = \sum_{k=1}^{K} S_k W_k$$

Figure 3. Candidate harmony equation

Each constraint C_k ($k = 1, ..., K$) is associated with a numerical weight W_k. A candidate's violation score on each constraint S_k is multiplied by the weight, and all constraint violations are then summed.

Because candidate optimality is determined by a numerical sum, as opposed to strict rankings, this allows for gang effects, wherein the violation of two or more low-weighted constraints sums to a greater penalty than the single violation of a higher-weighted constraint (Pater 2009b). Gang effects, however, cannot capture the dual vowel reduction pattern observed in Bolognese, as the distinguishing element between these two reduction patterns (raising or lowering of front mid vowels) is length, and all long inputs reduce to a short output, thus incurring the same number of violations of the faithfulness constraint MAX(μ), which assigns a violation for each mora deleted. As such, there is no asymmetric tradeoff between the violation of MAX(μ) and the actual winning candidate, as seen in the example Tableau (19).

(19)

/e:rˈb-eŋna/	LNP w = 3.5	IDENT[LOW] w = 2	IDENT[HIGH] w = 1.5	MAX(μ) w = 1	H
☞ a. [arˈb-eŋna]		-1		-1	-3
💣 b. [irˈb-eŋna]			-1	-1	-2.5
c. [e:rˈb-eŋna]	-1				-3.5

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level of /i/ is 1, /a:/ would have a sonority level of 6, /i:/ a sonority level of 2, and /ai/ a sonority level of 4.

(20)

/ʤarableˈn-eŋ/	LNP w = 3.5	Ident[Low] w = 2	Ident[High] w = 1.5	Max(μ) w = 1	*H*
a. [ʤarablaˈn-eŋ]		-1			-2
☞ b. [ʤarabliˈn-eŋ]			-1		-1.5
c. [ʤarableˈn-eŋ]	-1				-3.5

5.2. Scalar faithfulness as Max[F] and Dep[F]. While the well-adopted Ident[F] faithfulness constraint family (McCarthy & Prince 1995) disfavors any change in the specification of the feature *F*, Max[F] & Dep[F] disfavor the deletion or epenthesis of a specific featural specification (Zoll 1996; Lombardi 2001). If we posit that there exists a scalar [Sonority] feature, we can employ the constraints Max[Sonority] and Dep[Sonority] to generate the vowel reduction pattern observed in Bolognese.

(21) a. Max[Sonority]
Assign one violation for every level of sonority deleted.

b. Dep[Sonority]
Assign one violation for every level of sonority added.

These constraints assign violations in a similar way to the proposed Maintain(sonority) constraint. That is, there is a preference for segments to maintain their underlying sonority level, and any change in this value[9] results in scalar violation of the evaluating constraint.

In Tableau (22), Max[Sonority] assigns one violation to candidates *b*, *c*, and *d* for each change in sonority level, following the sonority thresholds in Figure 2 (§3.2, correctly predicting candidate *c* to be optimal. In Tableau (23), given the ranking Dep[Sonority] ≫ Max[Sonority], the violation of Dep[Sonority] by candidate *c* correctly predicts candidate *b* to be optimal.

(22)

/meːrˈd-eŋna/	Ident[Rnd]	LNP	Dep[Son.]	Max[Son.]
a. [meːrˈd-eŋna]		*! W		L
b. [mirˈd-eŋna]				***! W
☞ c. [marˈd-eŋna]				*
d. [murˈd-eŋna]	*! W			*** W

(23)

/pasteˈʎ-eŋna/	Ident[Rnd]	LNP	Dep[Son.]	Max[Son.]
a. [pasteˈʎ-eŋna]		*! W		L
☞ b. [pastiˈʎ-eŋna]				*
c. [pastaˈʎ-eŋna]			*! W	L
d. [pastuˈʎ-eŋna]	*! W			*

While a scalar [Sonority] feature coupled with the given ranking in Tableaux (22) and (23) could be used to generate the vowel reduction pattern in Bolognese, the very notion of a [Sonority] feature is problematic. Sonority, as is typically interpreted, is not a phonological feature, but a set of relationships between all segments. While various phonological patterns suggest that /a/ is more sonorous than /e/ (see Parker 2002), it is the positional relationship between these vowels

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[9] The hierarchical relation of the target segment to all other segments.

along the dimension of sonority that the grammar is sensitive to. If an input /e/ changes to an output /a/, it has increased its position along the sonority continuum. It is this positional relationship that the proposed scalar faithfulness constraint Maintain(sonority) evaluates; constraints that evaluate segmental features evaluate the presence or absence of a property between the input and the output, not a relationship between the input and the output. Additionally, the use of a scalar [Sonority] feature would imply that grammars could manipulate the sonority level of a segment without changing any of its other acoustic or articulatory properties. It is for these reasons that the proposal of a segmental feature [Sonority] is not adopted in this paper.

5.3. Local conjunction theory. One can consider an alternative analysis in Local Conjunction Theory (Łubowicz 2002; Smolensky 2006). In this theory, individual constraints can be conjoined into a single constraint, such that the conjoined constraint is violated if and only if their conjuncts are violated in the smallest domain (d) evaluated by them. To generate the Bolognese vowel reduction pattern, one could posit the conjoined constraint Max[μ] &$_D$ Ident[High], which is violated if both of the lower-ranking constraints Max[μ] and Ident[High] are also violated. Because candidate *a* in Tableau (24) both violates Max[μ] and Ident[High], it receives a violation of the conjoined constraint Max[μ] &$_D$ Ident[High]. In contrast, while candidate *a* in Tableau (25) does receive a violation of Ident[High], it does not delete any morae (avoiding a violation of Max[μ]), and thus avoid a violation of the conjoined constraint Max[μ] &$_D$ Ident[High].

(24)

/lumɛːˈg-eŋna/	Max[μ] &$_D$ Ident[High]	Ident[Low]	Ident[High]	Max[μ]
a. [lumiˈg-eŋna]	*! W	L	* W	*
☞ b. [lumaˈg-eŋna]		*		*

(25)

/studɛnˈt-eŋ/	Max[μ] &$_D$ Ident[High]	Ident[Low]	Ident[High]	Max[μ]
☞ a. [studinˈt-eŋ]			*	*
b. [studanˈt-eŋ]		*! W	L	*

While a constraint of this type could generate the dual reduction pattern at hand, Local Conjunction Theory is shown to make unmotivated typological predictions (Pater 2009a; Potts et al. 2010). There are no overt restrictions on which constraints can and cannot be conjoined. As such, for example, a grammar could be predicted in which specifically and only underlying long lax vowels (such as /ɛː/) remain fully faithful after vowel reduction, due to a high-ranking conjoined constraint like Max[μ] &$_D$ Ident[ATR]. In contrast, the notion that grammars can evaluate the relative sonority of two segments (§3) and the contribution of multiple independent phonetic factors on sonority (§3.1) is grounded in relatively established principles.

6. Remaining questions. While stress shift often results in vowel reduction only, there are exceptions. In this identical prosodic environment, that is, when there is a stress shift off the primary-stressed vowel due to the addition of a suffix, the short peripheral vowel /a/, the diphthong /ai/, and the long mid vowel /ɛː/ can delete.

(26) Examples of vowel reduction and vowel deletion

plain	*suffixed*	*gloss*
ˈsaɲːi	s∅ˈɲ-eŋ	‘sign’
ˈθasːt	θasˈt-eŋ	’basket’
ˈmail-a	m∅ˈl-eŋna	‘apple’
muˈnaid-a	muniˈd-eŋna	’coin’
aˈnɛːl	an∅ˈl-eŋ	‘ring’
kaˈnɛːl	kanaˈl-eŋ	‘canal’

Notable here is how not all vowels can delete. While there seems to be some correlation with sonority, where the vowels that undergo deletion tend to be relatively sonorous, I have not observed any deletion of similarly sonorous vowels (such as /eː/, /oː/, /ɔː/, and /aː/) in the data I have collected. This suggests that either there are further restrictions on the class of vowels that may be deleted, or that, should all vowels with a high level of sonority be eligible for deletion, /a/, /ai/, and /ɛː/ are among the most common vowels in the data collected.

Additionally, there appears to be no predictable environment in which deletion is favored, as made evident by the near-minimal pairs ‘ring’ and ‘canal’ in (26). Deletion appears to neither correlate with semantic identity (as there is no clear semantic relation between tokens) nor syllable count (given that the grammar tolerates an increase in syllable count per the usual process of vowel reduction, as described in (§2), preservation of underlying syllable count is unnecessary). Though deletion does appear to be favored when the vowel belongs to an existing suffix (e.g., /luk-**a**ˈt-eŋ/ → [luk-∅ˈt-eŋ]), the data in (26) shows that it is not possible to predict which root vowels undergo deletion.

In Osgan (in prep.), this alternation between vowel reduction and vowel deletion is analyzed as a lexical exception and is modeled via the use of gradient symbolic representations in Harmonic Grammar (Smolensky & Goldrick 2016; Hsu 2022).

7. Conclusion. This paper provides an account of the dual vowel-reduction pattern in Bolognese by proposing that the contradicting behavior of short and long mid vowels arises from their differing total sonority profiles. By treating vowel quality and quantity as independent contributors to sonority, and by introducing the scalar faithfulness constraint MAINTAIN(SONORITY), the analysis derives both reduction outputs within a single grammar. The proposal thus supports a broader theoretical claim: grammars may regulate input-output correspondence not merely in terms of binary features, but through sensitivity to scalar phonetic dimensions such as sonority. These findings inform broader phonological theories of sonority (Krämer & Zec 2020; Markopoulos & Apostolopoulou 2022) and provide a foundation for understanding how complex interactions among quality, quantity, and stress shape the structure of vowel systems.

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