Coarticulation affects faithfulness: evidence from subphonemically conditioned featural affixation in Laal

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Abstract This paper describes and analyzes the unusually complex multifeatural plural affix /Ⓛ[+high, +round]/ of Laal (endangered isolate), focusing on its most intriguing property: the realization of the [+round] subexponent is conditioned by the presence of a labial consonant in the base. Instrumental evidence shows that the conditioning factor is the rounding coarticulatory effect exerted on the vowel by the adjacent labial consonant. This is evidence that coarticulation has a role to play in phonology. Specifically, I show that the degree of faithfulness to a feature value [αF] can be weakened if the realization of that feature is affected by coarticulation. I propose an analysis utilizing both subfeatural representations and scalar faithfulness constraints, both of which are shown to be necessary. This analysis is shown to both confirm and supersede Steriade's (2009) P-map hypothesis. The subfeatural analysis is compared to an Agreement by Correspondence alternative, shown to be less satisfactory.

Keywords Multiple Feature Affixation · Subfeatures · Phonetic knowledge · Scalar weighted constraints · Laal

1 Introduction

In this paper, I describe and analyze a typologically rare case of featural affixation attested in Laal, and endangered isolate spoken by *ca.* 800 people in southern Chad. One of the many plural formation strategies of the language consists in changing the M tone of the singular to a L tone, and changing all the vowels of the singular base to [+high +round] if the base contains a labial consonant (1a), to [+high] otherwise (1b), as shown in example (1) below.

(1)		*singular*	*plural*			
	a.	ɓāgāl	ɓùgùl	'be tough'	M→L;	V→ [+high +round]
	b.	ɗāgān	ɗɨ̀gɨ̀n	'be light'	M→L;	V→ [+high]

I analyze this plural formation strategy as involving a non-segmental affix consisting of three subexponents: one floating tone and two phonological features: /Ⓛ [+ high, + round]/ (abbreviated as /-Lhr/). All three subexponents are replacive (Welmers 1973: 132-133), i.e. realized on all potential targets in the word.[1] I give arguments against a processual approach. Theory The focus of this paper is the analysis of the conditional realization of the floating [+ round] subexponent, which is the main analytical challenge posed by the Laal data. I give a phonetically grounded account, arguing that the realization of the floating [+ round] is conditioned by the presence of a partially rounded vowel in the base of affixation. This partial rounding is the consequence of the coarticulatory effect of an adjacent labial consonant, which explains the realization of [+ round] in (1a), but not in (1b). I provide supporting instrumental evidence showing that labial consonants significantly lower the F2 of adjacent [–round] vowels.

This analysis has several implications. First, it adds credence to a featural affix approach to similar suprasegmental morpho-phonological phenomena (McCarthy 1983; Lieber 1987, 1992; Wiese 1994; Akinlabi 1996; Ettlinger 2004; Wolf 2007; Trommer 2012; McPherson 2017, a.o.). It also brings additional evidence that multiple feature affixation is empirically supported, and that a constraint of the type REALIZE-MORPHEME van Oostendorp 2005 is not sufficient to account for featural affixation, as already claimed by Wolf (2005, 2007) and McPherson (2017), *contra* Trommer (2012). The Laal plural affix also illustrates a unique case of conditional featural affixation, where the conditioning factor is not featural compatibility –like in more well-known cases such as Chaha (McCarthy, 1983), Mafa (Ettlinger, 2004), and other Afro-Asiatic (among other) languages– but involves subphonemic properties –here, labial coarticulation. More generally, this case of conditional affixation supports the claim that coarticulation is visible to phonology, and must be represented in phonological theory. I claim that this is an argument in favor of the theory of SUBFEATURAL representations proposed by Lionnet (2017).

I propose a constraint-grammar implementation of this analysis. The general idea underlying this proposal is that faithfulness to coarticulated segments is weaker than faithfulness to non-coarticulated segments, i.e. by altering the perceptual cues to a particular feature borne by a segment, coarticulation makes this feature less resistant to change. In the present case, labial coarticulation makes a non-round vowel sound somewhat round, thus weakening faithfulness to the feature [–round] it bears. This idea is very close to the main intuition underlying Steriade's (2009) P-map hypothesis. The implementation I propose is, however, different from Steriade's. I represent the degree of coarticulation affecting the perceptual cues of a feature [F] with an intermediate value x of the subfeature $[\![x \text{ F}]\!]$ associated to [F]. Couching the analysis in Harmonic Grammar (HG; Legendre et al. 1990), I propose that faithfulness to [F] be scaled to the subfeatural value $[\![x \text{ F}]\!]$ associated with it. Violation of this scalar faithfulness constraint will thus yield higher penalties for changes affecting non-coarticulated (i.e. perceptually salient) [F] than coarticulated (i.e. perceptually less salient, or ambiguous) [F]. This explains the conditional realization of the [+ round] subexponent of the Laal plural affix: rounding a labialized [–round] vowel, i.e. a [–round] vowel that is perceived as somewhat rounded, is tolerated, as in (1a), while rounding a non-coarticulated [–round] vowel is not,

[1] Following Rolle (2018), I represent floating tones as superscript and circled Ⓣ, and docked floating tones as simply circled Ⓣ.

because the perceptual cues of rounding are unaffected and unambiguous. This reification of Steriade's P-map hypothesis is shown to be advantageous in §4.

I further show that a strict P-map account of the Laal data, following the formalism initially proposed by Steriade (2009) fails to account for the Laal data. The subfeatural approach proposed in this paper is thus shown to be an improvement of the P-map.

Finally, I consider a radically different alternative analysis couched in Agreement by Correspondence (ABC) theory (Hansson 2001, 2010; Rose and Walker 2004), which eschews the need for phonetic grounding and subfeatural representations. I show that both the subfeatural and the ABC analyses involve a heavy representational component. The representations necessary in the ABC account are however shown to be more stipulative, and less explanatory.

In §2, I introduce the language and describe the plural formation pattern that is the object of the paper. In section §3, I give an analysis of this pattern in terms of featural affixation, and analyze the realization of the L tone and [+high] feature of the affix in Harmonic Grammar. In section §4, I account for the realization of the [+round] feature of the affix. I first analyze in § 4.1 the role of the labial consonant, providing instrumental evidence of its strong and significant coarticulatory effect on a neighboring [–round] vowel. I then show in § 4.2 that there is independent evidence in Laal for the phonological effect of subphonemic labialization, namely a doubly triggered rounding harmony process analyzed in Lionnet (2017). In §§ 4.3 and 4.4, I propose a formalization of this analysis using subfeatural representations and scalar weighted constraints, proposing specifically that faithfulness to the [round] feature be scaled to the degree of coarticulation undergone by the potential target of rounding. This analysis is then compared to a more traditional P-map account in §5 and an Agreement by Correspondence analysis in §6, and shown to be superior to both. Section §7 concludes.

2 The data

2.1 Preliminary remarks on Laal

Laal is an language isolate spoken by about 800 people in two villages along the Chari river in southern Chad: Gori and Damtar, as well as in urban centers such as Sarh and N'Djaména. Prior work on the language was undertaken by Pascal Boyeldieu in the 1970's, who published a preliminary description of the sound system (Boyeldieu, 1977), as well as a description of the nominal and verbal systems (Boyeldieu 1982, 1987). All the data presented in this paper come from my own fieldwork: fifteen months between 2010 and 2018, with multiple speakers of various ages, both male and female, mostly in Gori, as part of language documentation project funded by the DoBeS (Documentation of Endangered Languages) program of the Volkswagen Foundation. No inter- or intra-speaker variation was found regarding the morpho-phonological alternation described and analyzed below. A recording of the relevant data can be found in the online DoBeS-Laal collection of The Language Archive hosted by the Max Planck Institute for Psycholinguistics in Nijmegen.[2]

[2] Path: Archive > DOBES > Archive > Laal > 1 Laal > Données/Data > 1-Données élicitées/Elicited data > 3 Morphologie/Morphology > GDM-Go_20150118_F_AK1_mialag-

Laal has 24 phonemic vowels: twelve short and twelve long, as shown in (2a). The vowel system is characterized by three degrees of aperture and an opposition between [+front] and [–front]. Both [+front] and [–front] vowels contrast in rounding.[3] The full inventory is attested only in the stem-initial syllable. Elsewhere, the inventory is reduced to the seven short vowels in (2b).

(2)	*a. Stem-initial (+length)*				b. *Elsewhere (–length)*		
	[+front]		[–front]				
	i	y	ɨ	u	i	ɨ	u
	e	ø	ə	o	e	ə	o
	ɛ	œ	a	ɔ		a	
	[–round]	[+round]	[–round]	[+round]			

Words in Laal are maximally disyllabic (CV∼CV(:)C.CVC), with only a few exceptions, mostly ideophones, frozen compounds, reduplicative forms and/or loanwords, ignored here. Derivational and inflectional morphology is suffixal: there are no prefixes. Finally, Laal has extensive vowel harmony: [+high] harmony, [±low] harmony, and rounding harmony –doubly triggered in stratum 1 phonology (morpheme structure constraints and number marking morphology) as we will see in § 4.2, and unconditioned in stratum 2 phonology (other inflectional and derivational morphology).

Laal has a singular vs. plural distinction, marked on both nouns (492/1,245 ≈ 40%) and verbs (130/463 ≈ 28%), as well as on pronouns and determiner-like elements, which agree with the noun they modify, determine, or refer to. In the vast majority of cases, number is marked through suffixation. Number marking morphology is complex, mostly unpredictable, and can be described as a collection of (mostly regular) subpatterns. There are over 30 number-marking suffixes, either singular or plural. Some are fairly frequent (e.g. 85 nouns form their plural with the suffix /-u/), some rather rare (eight are attested only once, eleven have more than one but less than five attestations). These suffixes may cause vowel changes in the root, most of the time through regular application of vowel harmony rules.[4] A few examples are given in (3).

(3)		*singular*	*plural*		
	a.	áár	ə́ə́r-ú	'sauce'	([±low] harmony)
	b.	pɛ́ɛ́l	péél-ì	'to stay awake'	([±low] harmony)
	c.	súgl-é	súgúl	'guineafowl'	
	d.	gùm-ál	gùm-ú	'melon (sp.)'	
	e.	ɲún	ɲún-ì	'go, walk'	
	f.	lūr	lūr-ā	'be short'	

rounding; URL: `https://archive.mpi.nl/islandora/object/lat\%253A1839_fa6fa707_7ddc_4a1b_a6cc_f8502f749150`

[3] The front/back contrast is captured by the feature [±front] (rather than [±back], or [+front,–back] vs. [–front,–back] vs. [–front,+back]), based on the effects of rounding harmony, whereby front vowels are rounded into front rounded vowels, and central vowels into back rounded vowels. Note, additionally, that /ɛ ɔ ø œ/ are most of the time realized as diphthongs: [e̯a o̯a ɥø∼ɥo ɥa], but are phonologically monomoraic (bimoraic when long).

[4] There exist a few plural suffixes whose effect on the root vowel is irregular, e.g. /-mi/ causes lowering of the root vowel instead of the expected anticipatory [±low] harmony: /gòò/ 'goat', pl. /gɔ̄ɔ̄-mī/ 'goats'.

In 52 nouns and 92 verbs, the number distinction is marked through purely tonal or featural changes. In most cases, the changes are the same as those caused by extant segmental suffixes, mostly through regular vowel harmony. These cases, illustrated in (4), are most likely derived from former suffixed forms whose suffix has dropped, leaving the tonal or featural change as the only trace of their past existence.

(4)	ndáár	ndə́ə́r	'skull'	cf. (3a) áár/ə́ə́r-ú
	pɛ́ɛ́	péé	'to pick up one by one'	cf. (3b) pɛ́ɛ́l/péél-ì
	mīīw	mìíw	'liver'	< *mììw-í?[5]

However, in some cases, the changes are different from those expected from vowel harmony. This is, for example, the case for most monosyllabic verbs of the form Ca(:)(C), which form their plural by raising the vowel /a/ to /ɨ/ (e.g. /kár/, pl. /kɨ́r/ 'put', /dāg/, pl. /dɨ̄g/ 'drag'). This is also the case of the multi-featural plural affix that is the object of the present paper.[6]

2.2 The multi-featural plural affix

The multi-featural plural affix /Ⓛ[+high, +round]/ is attested with 17 noun or verb bases (18 for some speakers, as we will see). These are all listed in (5). As can be seen, the singular is always mid-toned. The plural form is systematically L-toned and its vowels are all systematically [+high], irrespective of the vowels of the singular form. In /ɗāgān/, pl. /ɗɨ̀gɨ̀n/ in (5a), the lack of a labial consonant prevents the [+round] feature from being realized. All the words in (5b-d) include at least one labial consonant (word-initially in (5b), word-finally in (5c), both word-initially and elsewhere in (5d)), which allows the floating [+round] to be realized. The realization of [+round] in the forms in (5e) is masked by the fact that the vowels of the singular form are already underlyingly [+round]. The non-realization of [+round] is masked for the same reason in (5f). Finally, in /ɟūrūg/, pl. /ɟùrùg/ (5g), both the realization of [+high] and non-realization of [+round] are masked by the underlyingly [+high +round] vowels of the singular. At first sight, this alternation would seem to be better analyzed as a case involving only a tonal change (e.g. a floating, replacive L tone affix). I consider it to belong to the same paradigm fr two reasons. First, /ɟūrūg/, pl. /ɟùrùg/ is a stative verb expressing a quality, like all the other verbs compatible with this floating affix, and many of which have a very similar shape, in particular /mɛ̄lāg/, pl. /mʏ̀lùg/ and /bɛ̄rāg/, pl. /bʏ̀rùg/. More importantly, all the nouns and verbs whose singular is M-toned and whose plural is marked by a replacive L-tone belong to this paradigm, i.e. are listed in (5). If /ɟūrūg/, pl. /ɟùrùg/ were not considered to be part of this paradigm, it would be an isolated exception, which would not be satisfactory, since it can easily be

[5] Many body part terms form their plural with the suffix /-i/, e.g. /māl/, pl. /mə̀l-í/ 'tongue'. For the M → L change in the affixed form, see (14) and surrounding prose.

[6] There are also a few cases of suppletion (e.g. /nō/, pl. /muǎŋ/ 'person'), as well as isolated irregular forms, e.g. /diál/, pl. /dóy/ 'bracelet', /ɗīnyà/, pl. /ɗùny/ 'plant sp.'.

analyzed as involving the same /Ⓛ[+high, +round]/ affix as all the other words in (5).

(5)

					Ⓛ	[+hi]	[+rd]
a.	*No labial consonant:*						
	ɗāgān	/	ɗɨ̀gɨ̀n	'be heavy'	✓	✓	*
b.	*One labial consonant (word-initial):*						
	ɓāgāl	/	ɓùgùl	'be tough, hard'	✓	✓	✓
	mān	/	mùn	'be delicious'	✓	✓	✓
	bɛ̄rāg	/	bỳrùg	'be broad'	✓	✓	✓
	mɛ̄lāg	/	mỳlùg	'be red'	✓	✓	✓
	mə̄ə̄r	/	mùùr	'river'	✓	✓	✓
c.	*One labial consonant (word-final):*						
	tārīm	/	tùrùm	'*Distichodus sp.* (fish sp.)'	✓	✓	✓
	ɟārīm	/	ɟùrùm	'*Hyphaene thebaica* (tree sp.)'	✓	✓	✓
d.	*Two labial consonants:*						
	māāmār	/	mùùmùr	'buffalo'	✓	✓	✓
	pālīm	/	pùlùm	'*Ficus thonningii* (tree sp.)'	✓	✓	✓
e.	*Labial consonant, but V(s) is/are already round:*						
	bɔ̄ɲ	/	bùɲ	'be full'	✓	✓	(✓)
	mɔ̄ɲ	/	mùɲ	'disease, ilness'	✓	✓	(✓)
	mōr	/	mùr	'be tough (meat)'	✓	✓	(✓)
	dōrūm	/	dùrùm	'rope'	✓	✓	(✓)
f.	*No labial consonant, V(s) is/are already round:*						
	dōŋ	/	dùŋ	'be long'	✓	✓	(*)
	sōgōr	/	sùgùr	'be light'	✓	✓	(*)
g.	*No labial consonant, Vs are already high and round:*						
	ɟūrūg	/	ɟùrùg	'be deep'	✓	(✓)	(*)

Although all plural forms but two in (5) contain the same vowel [u], the forms /mɛ̄lāg/, pl. /mỳlùg/ (**mùlùg*) and /bɛ̄rāg/, pl. /bỳrùg/ (**bùrùg*) clearly show that V1 and V2 need not be identical, and that the feature [±front] is unaffected by the floating affix.

While this plural affix is not productive, it is clear that the words in (5) form a salient pattern, easily identifiable. A possible sign that the pattern is part of Laal speakers' knowledge comes from the plural form of the noun /tɔ̄gīm/ '*Sterculia setigera* (tree sp.),' which was given to me in three different forms by different speakers: /tɔ̄gīm/ (invariable), /tōgm-ōr/ (with the otherwise attested /-or/ plural suffix), and /tùgùm/, with the /Ⓛ [+high +round]/ affix, possibly by analogy with morphologically and semantically similar words such as /ɟārīm/, pl. /ɟùrùm/ '*Hyphaene thebaica* (tree sp.)', /pālīm/, pl. /pùlùm/ '*Ficus thonningii* (tree sp.)', and /tārīm/, pl. /tùrùm/ '*Distichodus sp.* (fish sp.).'

Additionally, the fact that all the bases of affixation but one (/ɗāgān/) contain either a labial consonant or a round vowel shows the affinity between the multifeatural plural affix and labiality/rounding.

Three criteria are particularly interesting, and will prove important in the analysis: the presence vs. absence of a labial consonant in the base of affixation, the length of the base of affixation (mono- vs. disyllabic, important because in disyllabic words with only one labial consonant, both vowels undergo rounding, including the one that is not adjacent to the labial consonant), and the frontness of the target vowel (both [+front] and [–front] vowel are be targeted). Inevitably with such a small number of attested cases, there are gaps, most likely accidental. There is, for instance, only one form illustrating the non-realization of floating [+round] for lack of a labial consonant: /ɗāgān/, pl. /ɗìgìn/. There is, consequently, no illustration of the non-realization of [+round] with a front vowel (e.g. */nɛ̄lāg/, predicted plural */nìlìg/ in Table 1), or in a monosyllabic word (e.g. */ɗāg/, predicted plural */ɗìg/ or */ɗɛ̄g/, predicted plural */ɗìg/), and no illustration of the realization of [+round] on a monosyllabic word with a [+front] vowel (e.g. */mɛ̄n/, predicted plural */mỳn/). Table 1 below lists all possible combinations of the three criteria listed above, with predicted forms filling the gaps. The predicted plural forms are based on what is known from attested forms: one can indeed expect rounding of both [–front] (/ɓāgāl/, pl. /ɓùgùl/) and [+front] vowels (/mɛ̄lāg/, pl. /mỳlùg/) in the presence of a labial consonant, in both monosyllabic (/mān/, pl. /mùn/) and disyllabic (/ɓāgāl/, pl. /ɓùgùl/) words. We will see that these accidentally unattested forms and their expected behavior have an important role to play the analysis. Unattested, hypothesized forms are preceded by an asterisk throughout the paper.

Table 1: Attested data and accidental gaps illustrating all possible combinations of factors (shading indicates realization of the floating [+round])

		1 syllable	2 syllables
No lab C	[+front]	*ɗɛ̄g/*ɗìg	*nɛ̄lāg/*nìlìg
	[–front]	*ɗāg/*ɗìg	ɗāgān/ɗìgìn
Lab C	[+front]	*mɛ̄n/*mỳn	mɛ̄lāg/mỳlùg
	[–front]	mān/mùn	ɓāgāl/ɓùgùl

3 A featural affixation analysis

3.1 A case of multiple-feature affixation

Since the alternation illustrated in the previous section does not involve any overt segmental morpheme, but only featural and tonal changes, it could easily be analyzed as a case of process- rather than item-based morphology. The process marking plurality would involve three simultaneous changes: M → L, [–high] → [+high], and [–round] → [+round], the latter only in the presence of a labial consonant. I contend that the featural affix approach is preferable. Indeed, since number-marking morphology (and in general all inflectional and derivational morphology) is mostly marked by segmental suffixes in Laal, it is much more economic to analyze nonsegmental number-marking morphological processes using the same machinery. The only irrefutable argument in favor of a processual approach would be the impossibility to determine an underlying representation for the floating affix (cf. Sande 2017, 2018), which is not the case here.

One could argue that the impossibility to linearize the floating plural affix militates against a concatenative, item-based approach. Indeed, since all the features of the /Ⓛ[+high, +round]/ affix are replacive, this affix can equally be analyzed as a prefix, suffix, infix, or circumfix. But this argument is rather weak. Not only is positing affixes that are underspecified for linearization not a problem *per se*, it might actually be required in cases of mobile affixation (Fulmer 1991; Noyer 1994; Rucart 2006; Kim 2008, 2010; Jenks and Rose 2015). In general, it is known that suprasegmental properties tend to have more “spatial” freedom than segments. It is only expected that non-segmental affixes should enjoy the same freedom.[7] Note that, for convenience, I will henceforth represent the featural affix as a suffix (there aren’t any prefixes in Laal). I will also treat floating tones on a par with floating features.[8]

In this concatenative approach, the floating plural affix of Laal is not only analyzed as a featural affix, but as a case of multiple feature affixation, i.e. one morphosemantic feature exponed by more than one phonological feature. Trommer (2012) claims that multiple feature affixation does not exist. He reanalyzes all the claimed cases of multiple feature affixation as involving several mono-featural morphemes. For example, the negative present participle suffix [–voice, –continuant] and the past participle suffix [–voice, +continuant] of Nuer (/guð/ ‘pull out.INF’, /gut̪/ ‘pull out.NEG.PRES.PART’, /guθ/ ‘pull out.PST.PART’) are reanalyzed as involving the three following mono-featural morphemes: [–voice] PARTICIPLE, [+continuant] PAST, and [–continuant] NEGATIVE. However, as argued by McPherson (2017) for Seenku, ‘plural’ is an atomic morphosyntactic feature that cannot be subdivided into several morphemes. The featural plural affix /Ⓛ[+high, +round]/ of Laal can thus only be analyzed as a case of multiple feature affixation.

3.2 Constraint-based analysis

In this and the following sections, I give a constraint-based analysis of the realization of the multi-featural plural affix, couched in Harmonic Grammar (Legendre et al. 1990; Smolensky and Legendre 2006). The reason for this choice of framework will become clear in §4. Weights, calculated with the OT-Help 2 software (Staubs et al. 2010), correspond to the minimum values necessary to make the correct predictions, with weights restricted to positive real numbers, and the minimum weight value set to 1. Only partial illustrative tableaux will be given in each relevant section. Weights will be adjusted as new constraints are added. Full, cumulative tableaux are given in Appendix B.

Three main points need to be account for in the analysis: 1) the realization of floating features and tone; 2) the conditional realization of the [+round] feature and the role played by the labial consonant (dealt with in §4); and 3) the replaciveness of the floating features and tone. I will start with the latter, which is not the

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7 In a constraint-based framework, the underlying linearization of the affix is irrelevant, since any linearization in the input (prefix, suffix, etc.) will systematically yield the same optimal output.

8 Although I analyze this affix as consisting of two features and a tone, a fully featural analysis is also possible, if one analyzes the tone system of Laal using Pulleyblank’s (1986) tonal feature system, adapted from Yip (1980). The tonal scale would be divided into two registers: [+upper] containing only H, and [–upper] consisting of both M = [–upper, +raised] and L = [–upper, –raised]. There are indeed arguments in favor of considering M and L to form a natural class [–upper] (see the M→L rule in (14) below). The multi-featural plural affix would thus be represented as [(–upper), –raised, +high, +round], involving only binary features. This would not fundamentally change the analysis.

main point of this paper, and is to a large extent independent of the issues raised later regarding the analysis of the realization of floating affixal material: the constraints accounting for replaciveness will apply irrespective of the chosen analysis.

3.2.1 Accounting for replaciveness

To account for the replacive nature of the floating affixal material, I resort to two alignment constraints (McCarthy and Prince (1993)) requiring that floating material be aligned with both edges of the word: FLT-L and FLT-R, defined in (6) and (7).

(6) FLT-L = ALIGN(Flt, L, Word, L): Align any floating feature or suprasegment to the left edge of the word. Assign one violation per floating feature or suprasegment that is not associated with the leftmost segment on the relevant tier (vowel tier for vocalic features, TBU tier for tones).

(7) FLT-R = ALIGN(Flt, R, Word, R): Align any floating feature or suprasegment to the right edge of the word. Assign one violation per floating feature or suprasegment that is not associated with the rightmost segment on the relevant tier (vowel tier for vocalic features, TBU tier for tones).

Note that both constraints are necessary given the non-linearization of the plural /Ⓛ[+high, +round]/ affix. The tableau in (8) shows how these two alignment constraints enforce replaciveness of the L tone in /ɗāgān-Ⓛ[+high, +round]/ → [ɗìgìn] (showing only the relevant near-optimal candidates where the other two subexponents are realized ([+high]) or not ([+round]), as expected.[9]

(8)

ɗ ā g ā n (M) [+hi, +rd] Ⓛ	FLT-L $w = 1$	FLT-R $w = 1$	H
a. ɗ ī g ì n (M, Ⓛ)	−1		−1
b. ɗ ì g ī n (Ⓛ, M)		−1	−1
☞c. ɗ ì g ì n (Ⓛ)			0

These two constraints apply to all and only affixal floating features and tones, which are the only ones that are replacive in Laal. Underlyingly linked features and tones are indeed never replacive (cf. Appendix C). Additionally, floating tones are only replacive when they are associated with an affix, never when associated with a root. There are two nouns in Laal that must be analyzed as ending with a floating H tone, to account for their otherwise inexplicable tonal behavior: they assign an

[9] Note that gapped configurations (skipping a vowel or TBU) are not a problem in Laal, since words are maximally disyllabic. If longer words were attested one would need an undominated constraint penalizing gapped configurations.

unexpected H tone to a following L-toned possessive suffix, as shown in as shown in (9a).

(9) a. L-toned nouns with floating H-tone:

/nàrⒽ-ər/	[nərə́r], *[nərər]	'my son'
/nɨ̀rⒽ-ər/	[nɨ̀rɨ́r], *[nɨ̀rɨ̀r]	'my daughter'

b. L-toned nouns:

/bàl-ər/	[bə̀lə̀l]	'my husband'
/ˀjàw–ər/	[ˀjə̀wə̀r]	'my paternal aunt'

c. H-toned nouns:

/tɨ́m-ər/	[tɨ́mɨ́r], *[tɨ́mɨ̀r]	'my hand'
/mág-ər/	[mə́gə́r], *[mə́gə̀r]	'my vagina'

L-toned nouns (9b) do not assign this extra H tone. However, H-toned nouns spread their H-tone one mora to the right , delinking the L-tone of a following L-toned possessive suffix, as illustrated in (9c). The floating H in /nàrⒽ/ and /nɨ̀rⒽ/ thus simply undergoes this regular H-spread rule. Note that these two floating tones are not replacive. The generalization is thus that affixal floating tones are systematically replacive, but not floating tones associated with roots (of which there are only two cases, illustrated in (9) above) (see Appendix C for more on replacive tones in Laal).

The alignment constraints defined above (or any other constraints proposed to account for the replaciveness of affixal floating features in Laal) must thus refer to both details of the underlying representation of tones and features (floating vs. linked), and the morphological category to which they are associated (affixal vs. non-affixal).

These two alignment constraints are stipulative, and cannot be considered a satisfactory account of replaciveness.[10] Since the focus of this paper is the conditional realization of the floating [+round], and not the replaciveness of the floating features, these constraint will suffice here. I will henceforth combine the two ALIGN constraints into one (FLT-L&R), to save space in tableaux.

3.2.2 Accounting for the realization of floating L and [+high]

Accounting for featural affixation in Optimality Theory requires a (set of) constraint(s) enforcing the realization of the floating feature(s)/tone(s) on segmental material from the base of affixation, possibly overwriting featural/tonal specifications of the base. As summarized by Trommer (2012) (see also McPherson 2017), four approaches have been proposed: markedness constraints *[F] favoring the realization of the (unmarked) floating feature at the expense of the (marked) feature it overwrites; featural faithfulness constraints of the MAX[F] family enforcing the realization of the floating feature (Lombardi 1995, 1998); REALIZE-MORPHEME (van Oostendorp 2005), defined in (10), requiring morphemes to be (at least partially) phonologically realized; and a specific MAXFLT constraint (Wolf 2005, 2007), defined in (11), penalizing the non-realization of floating features, irrespective of their markedness status.

[10] For more on replacive tone and its analysis in Optimality Theory, see Rolle (2018), and references therein.

(10) Realize-Morpheme For every morpheme in the input, some phonological element should be present in the output. (van Oostendorp 2005)

(11) MaxFlt: All autosegments that are floating in the input have output correspondents (Wolf, 2007)

The Realize-Morpheme approach can already be excluded. As previously shown by McPherson (2017), it cannot account for cases of multiple feature affixation, since partial realization of the morpheme (e.g. only one of the three subexponents of the plural affix in Laal) is sufficient to satisfy it.

Of the three remaining approaches, *[F] and Max[F] are the most economic, since they refer only to phonological properties, and use only classic constraints that are independently needed in phonological theory. MaxFlt refers to the floating vs. linked status of features, and seems to be motivated only by featural affixation, making it both more *ad hoc* and less economic. On the basis of economy, an analysis of featural affixation should resort to the latter only if neither of the two phonological approaches is possible. In the remainder of the paper, I will show that a phonological approach is both possible and confirmed by independent evidence, and will propose an analysis utilizing Max[F] constraints (in this section and §4).[11]

Resorting to either markedness or Max[F] constraints only works if the floating features at stake are systematically less marked than the base feature they overwrite. A floating feature [αF] is realized to the detriment of the root [$-\alpha$F] only if *[$-\alpha$F] > *[αF], or Max[αF] > Max[$-\alpha$F]. This only works if there are no cases in the language which would require the reverse weighting relation *[αF] > *[$-\alpha$F] or Max[$-\alpha$F] > Max[αF]. Neither of these two solutions would thus extend, for example, to a language like Nuer, where both values of the feature [continuant] are attested in two featural suffixes: the [–continuant] negative suffix requires *[+cont] > [–cont] or Max[–cont] > Max[+cont], and the [+continuant] past suffix requires the reverse order (Trommer 2012).[12]

There is ample evidence in the morphophonology of Laal that this is indeed the case, i.e. that M, [–high], and [–round] are more marked than L, [+high] and [+round] respectively. Regarding the two vocalic features, no high vowel is ever lowered, nor any round vowel unrounded. Additionally, both [+high] and [+round] harmony are robustly attested in the language. Both harmonies are illustrated in (12), where the root vowel is rounded by the suffix vowel through regular anticipatory rounding harmony, and the suffix mid vowel raised to [+high] under the effect of the [+high] root vowel through regular persevatory [+high] harmony targeting mid vowels (cf. Lionnet 2017).

(12) /pɨ́r-ò/ → [púrù] 'catch-her'

The realization of these two subexponents of the /Ⓛ[+high, +round]/ floating affix would thus be straightforwardly accounted for by either the *[F] or the Max[F] approach (*modulo* the conditionality of the realization of [+round], which I will turn to in §4). I show in § 4.5.3 that the *[F] approach fails to account for the

[11] See Appendix C for potential evidence that MaxFlt might be independently necessary to account for all cases of featural affixation in Laal, but must coexist with Max[F] constraints.

[12] Although see Appendix C and McPherson (2017) for a possible way to maintain a markedness-hierarchy-based account of such contradictory data.

conditional realization of [+ round], and consequently use only MAX[F] constraints in the remainder of the paper. Tableaux (13) illustrates the realization of [+ high] in /ɗāgān/ → [ɗȉgȉn] (showing only near-optimal candidates where L is realized and [+ round] is not, as expected from the optimal candidate).

(13) MAX[+ high] > MAX[–high] for the realization of [+ high] in /ɗāgān/ → [ɗȉgȉn]

ɗ ā g ā n [–hi] [+hi +rd] Ⓛ	FLT-L&R $w = 2$	MAX[+ high] $w = 2$	MAX[–high] $w = 1$	H
a. ɗ à g à n [–hi]		−1		−2
b. ɗ à g ȉ n [–hi] [+ hi]	−1			−2
☞c. ɗ ȉ g ȉ n [+ hi]			−1	−1

In the tableau in (13), the weight relation MAX[+ high] > MAX[–high] systematically enforces the realization of the floating [+ high] feature, knocking down candidates (13a) [ɗàgàn], where it is not realized. FLT-L&R, appropriately weighted with respect to MAX[+ high] ensures that this feature is realized on both vowels (13c), rather than on only one of them (13b).

There is also evidence that M is more marked than L. In particular, word-level tone patterns involving M and either H or L are both unattested and actively avoided. Whenever such a pattern would emerge from the concatenation of a M-toned root and a L- or H-toned suffix, the M tone of the root is systematically changed to L, as illustrated in (14).[13]

(14)	a.	/dāg/	→	[dāg]	‘drag’
	b.	/dāg-àn/	→	[dàgàn], *[dāgàn]	‘drag-it’
	c.	/dāg-án/	→	[dàgán], *[dāgán], *[dágán]	‘drag-him’

MAX-L > MAX-M thus easily accounts for the realization of the floating L subexponent of the plural affix, following the same rationale as for the realization of [+ high] in (13) above. This is shown in tableau (15).

[13] The tone strength hierarchy in Laal is H > L > M, as shown by the M→L rule illustrated in (14) (L > M), and by the High Tone Spread rules illustrated in (**??**) and (55a) in Appendix C, whereby a H tone spreads and delinks a following suffixal L tone (H > L). See Appendix C for an exception to the relative markedness of M with respect to L. MH and HM are marginally attested in a few grammatical words, as well as recent non-integrated loans; LM is only attested in a dozen recent loans; ML is unattested. Most well-integrated loanwords which have a MX or XM tone in the source language have a tone pattern in Laal that complies with the *XM/MX constraint.

(15) MAX-L > MAX-M for the realization of L in /ɗāgān/ → [ɗìgìn]

ɗ ā g ā n M $\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ Ⓛ	FLT-L&R $w=2$	MAX-L $w=2$	MAX-M $w=1$	H
a. ɗ ī g ī n M		−1		−2
b. ɗ ī g ì n M Ⓛ	−1			−2
☞c. ɗ ì g ì n Ⓛ			−1	−1

In conclusion, a purely phonological approach to the realization of floating features is sufficient. The most satisfying approach resorts to MAX[F] constraints (markedness *[F] constraints will be shown to unable to account for the realization of [+round] in § 4.5.3). REALIZE-MORPHEME is incapable of accounting for multiple feature affixation (McPherson 2017), and there is no need to resort to uneconomic MAXFLT.[14]

4 The conditional realization of [+round]

In this section, I turn to the analysis of the realization of the [+round] subexponent of the plural affix, which we saw is conditioned by the presence of a labial consonant in the base of affixation. I first discuss the role played by the labial consonant (§ 4.1), then give independent evidence for the relationship between base labial consonants and the realization of affixal [+round] (§ 4.2), and finally propose an account of this conditional realization using subfeatural representations (§ 4.3) and scalar weighted constraints in Harmonic Grammar (§ 4.4).

4.1 The role of the labial consonant

I contend that the role of the labial consonant is to be understood in terms of coarticulation and its perceptual correlate: the [+round] subexponent of the affix is realized only if at least one vowel in the word is partially rounded through coarticulation with a neighboring labial consonant. This partial rounding effect (transcribed with a superscript capital $^{\mathrm{B}}$) can be schematically stated as the rule in (16):

(16) /V/ → [V$^{\mathrm{B}}$] / {B__, __B} (B = labial consonant)

Instrumental evidence largely supports this claim: labial consonants in Laal have a strong coarticulatory effect on the preceding and following vowel, significantly lowering the F2 value of these vowels. The relevant coarticulatory effect here is the one observed between labial consonants and the high non-round vowels [i] and [ɨ],

14 See Appendix C for potential evidence that MAXFLT might be independently needed in Laal, without eschewing the need for MAX[F] constraints.

since these are the vowels that would surface were the [+ round] feature to be left unrealized in /miālāg-Lhr/ → *[mìlɨ̀g] and /ɓāgāl-Lhr/ → *[ɓɨ̀gɨ̀l].

Lionnet (2017) shows that labial consonants have a significant F2 lowering effect on neighboring [ɨ], as can be seen on Figures 1 and 2. Since the lowering of F2 incurred by the B__ and __B conditions is of similar magnitude, both are collapsed into one single category [ɨ^B] on the plots.

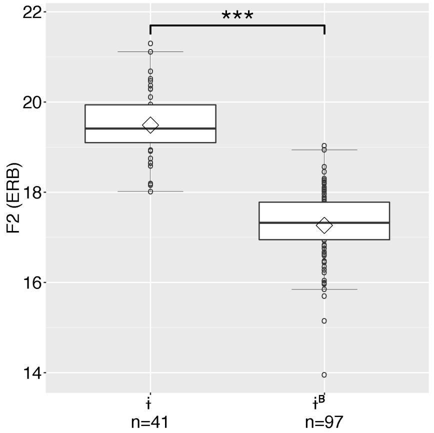


Fig. 1: Overall effect of B condition on F2 of [ɨ] (Lionnet 2017)

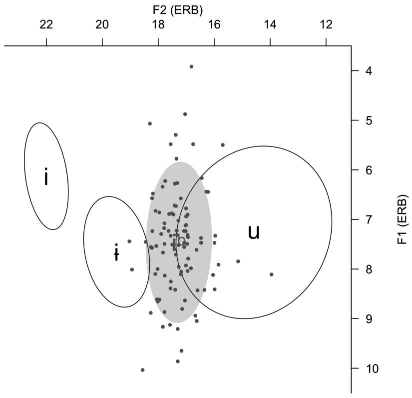


Fig. 2: [ɨ^B] (= [ɨ]/B_ and [ɨ]/_B) plotted against [i], [ɨ], and [u] (Lionnet 2017)

As can be seen on Figures 1 and 2, the F2 lowering effect incurred by a labial consonant on [ɨ] is both very strong, and very significant: [ɨ^B] is on average 2.22 ERB (402 Hz) lower in F2 than [ɨ] ($t(75) = 15.4$, $p = 2.20e^{-16}$***).

I now present additional data on the effect of labial consonants on the front vowel [i]. The following measurements were obtained using the same methodology as Lionnet (2017). Words illustrating labialized [i^B] and non-labialized [i] conditions were recorded from Adoum Kalem (AK), 30 year-old native Laal speaker. Recordings were made using a Zoom H4n recorder set at a sample rate of 44.1 kHz and 16-bit sample size, and a mono Røde NTG2 condenser shotgun microphone. The first three formants of the stem-initial vowel were extracted with Praat (Boersma and Weenink, 2014) at the midpoint of the total vowel interval, i.e. as far as possible from formant transitions. Formant frequency values in Hertz were then converted into Equivalent Rectangular Bandwidth (ERB), using Moore and Glasberg's (1983) equation, to better approximate human perception. The results are summarized in the plots in Figures 1 and 2.[15]

[15] The list of words illustrating the vowels [i], [i^B], and [y] included in the instrumental study can be found in Appendix A. The original sound files can be found in the online DoBeS-Laal collection of The Language Archive hosted by the Max Planck Institute for Psycholinguistics in Nijmegen.(Path: Archive > DOBES > Archive > Laal > 1 Laal > Données/Data > 1-Données élicitées/Elicited data > 3 Phonologie/Phonology > GDM-Go_20180622_F_AK1_Elicitation-vowels-i-ib-y; URL: `https://archive.mpi.nl/islandora/object/lat\%253A1839_ec872fcd_1248_41d2_bfcb_af9b039fdc12`

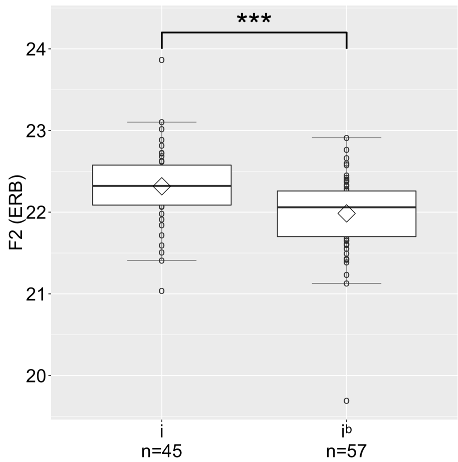


Fig. 3: Effect of a labial consonant on F2 of [i]

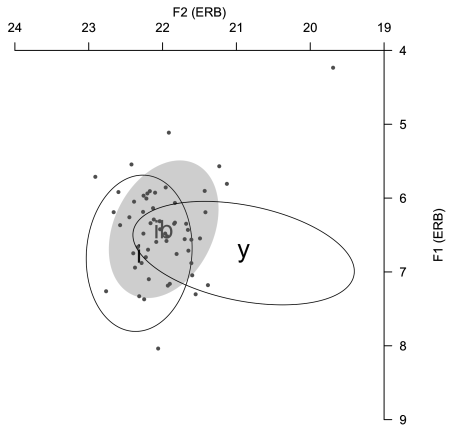


Fig. 4: [i^{B}] plotted against [i] and [y]

As can be seen in Figures 1 and 2, the effect of a labial consonant on a neighboring front vowel [i] is much less spectacular than on [ɨ], but still important and significant: [i^{B}] is on average 0.34 ERB (92 Hz) lower in F2 than [i] ($t(96) = 3.5$, $p = 0.0008$***). In both cases, the labial consonant has no significant effect on F1 or F3: only F2 is affected.[16]

I claim that these differences are perceptible in Laal. Although I have not tested this claim experimentally, it is not far-fetched to think that a 402 Hz F2 difference might easily be perceptible. The perceptibility of the average 92 Hz F2 difference between [i] and [i^{B}], on the other hand, requires more caution. Kewley-Port (2001) found that the formant discrimination threshold for untrained native US listeners for a 2400 Hz frequency (which is about the average F2 of [i] in AK's speech: 2366 Hz) was 111 Hz. The 92 Hz difference noted in AK's speech is below that threshold (it corresponds to the discrimination threshold found for $F = 2000$ Hz in Kewley-Port's study). This, of course, does not prove that this difference is not perceptible for Laal speakers. Kewley-Port (2001) found that trained native US English speakers can discriminate a mean F2 difference of 63 Hz in [bɪd] (F2 $\approx$2300Hz). Given the importance of subphonemic effects of this sort in the phonology of their language (cf. § 4.2 and Lionnet 2017), it is not unlikely that Laal speakers are naturallly "trained" to perceive them. One also needs to consider that the mean difference in F2 between [i] and [y] is only 360 Hz (vs. 756 Hz between [ɨ] and [u]), and that [i] and [y] have partially overlapping distributions (contrary to [ɨ] and [u], as shown in Figure 2). Since the vowel space is more crowded in the front region, one might expect that speakers are sensitive to smaller F2 differences among front vowels. Finally, it is also possible that the visual cues associated with lip rounding or constriction help auditory cues in making [i] and [i^{B}] perceptually distinct.[17]

[16] Laal is not the only language where this lack of correlation between labial constriction and F3 has been noted: see, for example, McCollum (2018) about Kazakh.

[17] Keith Johnson, p.c., October 1st, 2018.

4.2 Independent evidence: the doubly triggered rounding harmony

The realization of the multifeatural plural affix /Ⓛ[+high, +round]/ is not the only morpho-phonological phenomenon in which the subphonemic coarticulatory effect of labial consonants on neighboring vowels is at work in Laal. Indeed, as shown in Lionnet (2017), Laal also has a rare case of doubly triggered anticipatory rounding harmony, whereby the initial vowel of a word (V1) is rounded by a following round vowel (V2) if and only if V1 is next to a labial consonant (LabC condition). Two additional trigger-target similarity preconditions apply: both vowels must be of equal height (αheight condition) and backness specification (βfront condition). This is illustrated in (17a) below. All the conditions need to be met for the harmony to occur, as clearly shown by the non-application of the harmony in (17b-d), where one condition is missing in each example.

(17)					LabC	αheight	βfront
	a.	/ɓɨ̀r-ú/	[ɓùrú]	'hook-pl'	✓	✓	✓
		/tə̀b-ó/	[tòbó]	'fish(sp.)-pl'	✓	✓	✓
	b.	/gɨ́n-ù/	[gɨ́nù]	'net-pl'	*	✓	✓
	c.	/ɓə̀r-ú/	[ɓə̀rú]	'plant-pl'	✓	*	✓
	d.	/bìrú/	[bìrú]	'burn'	✓	✓	*

On the basis of phonetic measurements, some of which are reproduced in § 4.1 above, Lionnet (2017) shows that the doubly triggered rounding harmony targets only the natural class of subphonemically labialized vowels: [ɨ^{B}] and [ə^{B}]. These must therefore be recognized as forming a natural class excluding their non-labialized counterparts [ɨ ə], which implies that the non-contrastive labial coarticulatory effect distinguishing them must be represented in the phonological grammar. I come back to this question of representation in the next section.

What is important to note here is that there are two independent morpho-phonological phenomena in Laal that require the phonological grammar to refer to the subphonemic labialization resulting from labial coarticulation. Crucially, these two phenomena actually exhaust the number of contexts in which the realization or spreading of a [+round] feature is at stake within stratum-1 phonology (which consists of morpheme structure constraints and number marking morphology). In other words, every time a [+round] feature must be realized (be it affixal or part of the root, underlyingly floating or linked to a segment) in stratum-1 phonology, this realization interacts with subphonemically labialized vowels. The subphonemic effects of labial coarticulation can thus be said to be active, i.e. relevant to phonological computation, in the entire domain of stratum-1 phonology in Laal.[18]

4.3 Subfeatural representations

To represent such subphonemic distinctions as those at work in stratum-1 phonology in Laal, Lionnet (2017) proposes to enrich phonological theory with SUBFEAT-

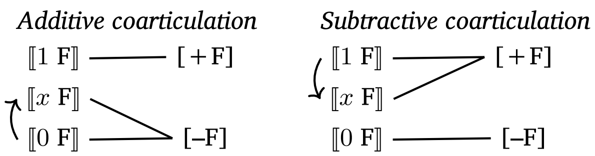
[18] Subphonemic labialization is, on the other hand, inactive in stratum-2 phonology (regular inflectional and derivational morphology other than number marking), where [+round] harmony is unconditional, and insensitive to subphonemic rounding (cf. Lionnet 2017: 532–533).

URAL representations. In this section, I briefly summarize his theory of subfeatural representations. The reader is invited to refer to Lionnet (2017) for more details.

Lionnet proposes to divide the feature system into two substantively related subsystems. Binary features represent contrastive categories, e.g. [–round] vowels /i e ɛ ɨ ə a/ vs. [+round] vowels /y ø œ u o ɔ/ in Laal. These contrastive featural categories are associated with non-contrastive, perceptually distinct subfeatures. These subfeatures represent perceptual information about the realization of the contrastive feature they are associated with, and are thus sensitive to contextual realization and coarticulatory effects. Subfeatures (represented with double square brackets) are thus scalar representations that capture the gradient subphonemic effects triggered by coarticulation, and are subordinate to the binary features used to represent phonemic contrast: [±F] $\leftrightarrow$ ⟦x F⟧.

Contrastive categories correspond to full subfeatural values, i.e. [–F] and [+F] are by default associated with the subfeatural values ⟦0 F⟧ and ⟦1 F⟧ respectively, unless coarticulation applies. Coarticulatorily driven subphonemic distinctions are encoded whenever relevant with intermediate subfeatural values x ($0 < x < 1$) on the subfeatural scale. Coarticulation affecting the perceptual correlates of a feature [F] can be either additive or subtractive. It is additive, i.e. it increases the subfeatural value from ⟦0 F⟧ to ⟦x F⟧, when the target of coarticulation is specified as [–F], i.e. the initial subfeatural value associated with the affected feature is ⟦0 F⟧ (as in the case of labial coarticulation in Laal). It is subtractive in the opposite scenario, i.e. when the target of coarticulation is specified as [+F] and the initial subfeatural value associated with the affected feature is ⟦1 F⟧, in which case it decreases the subfeatural value from ⟦1 F⟧ to ⟦x F⟧. This is illustrated in (18).

(18)



Labialization in Laal is a case of additive coarticulation. The perceptual rounding scale, corresponding at the contrastive level to the binary feature [+round] vs. [–round], is represented as a continuum between ⟦0 round⟧ and ⟦1 round⟧. Canonical, non-coarticulated [–round] and [+round] vowels are ⟦0 round⟧ and ⟦1 round⟧ respectively. Labialized [–round] vowels, on the other hand, are not ⟦0 round⟧ anymore, but ⟦x round⟧ ($0 < x < 1$), where x indicates the amount of rounding/labial coarticulation affecting the segment bearing the feature [–round]. The [–round] category is thus subdivided into two subfeatural categories in Laal: ⟦0 round⟧ vowels [i e ɜ ɨ ə a], which do not have any of the perceptual correlates of rounding, and ⟦x round⟧ [iᴮ ɨᴮ əᴮ], which are partially rounded, i.e. have some proportion *x* of the phonetic properties that characterize canonical round vowels. Labial coarticulation thus increases the subfeatural ⟦round⟧ value from 0 to x. This is illustrated in (19) with high vowels (the only ones that are relevant for this paper).[19]

19 /i ɨ ə/ are the only three vowels so far for which there is evidence that labialization is distinctive and plays a role in their phonological behavior (cf. Lionnet 2017).

(19) *Labial coarticulation in Laal high vowels:*

⟦1 round⟧	[y u]	[+ round]
⟦x round⟧	[i^{B} ɨ^{B}]	
⟦0 round⟧	[i ɨ]	[–round]

Subfeatures are a representation of language-specific phonetic knowledge (Kingston and Diehl 1994), defined by Hayes and Steriade (2004: 1) as "the speaker's partial understanding of the physical conditions under which speech is produced and perceived." ⟦x round⟧ represents the knowledge that Laal speakers have of the labial coarticulation affecting a vowel and its perceptual correlate. In Laal, ⟦x round⟧ represents the amount of coarticulation undergone by a vowel, which can be calculated, on the basis of the acoustic data presented in Figures 1 to 4 above, as ⟦.47 round⟧ for [ɨ^{B}] and ⟦.26 round⟧ for [i^{B}]. In other words, [ɨ^{B}] is 47% more round (closer to [u]) than [ɨ], and [i^{B}] 26% more round (closer to [y]) than [i] on average.

The [+ round] floating feature of the plural affix can thus be said to be sensitive to the labialization of its potential target of realization: it is only realized on a vowel that is at least ⟦.26 round⟧. The presence of such a vowel in the base of affixation is a necessary condition for this feature to be realized. The fact that the feature gets realized on all the vowels of the base, i.e. on both labialized and non-labialized vowels, e.g. [ɓùgùl] (not *[ɓùgɨ̀l]) can be explained by the fact that [+ round] is replacive, like any other floating feature in the language. In other words, the feature cannot be realized if there is no ⟦≥.26 round⟧ vowel in the base of affixation, but if it is realized, it must be realized on all the vowels in the base. In a rule-based account, docking of [+ round] on the ⟦≥.26 round⟧ vowel could be said to occur first, followed by spreading of [+ round] to the remaining vowel to satisfy the replacive nature of the feature, as illustrated in (21-23) below. (We will see in § 4.4.3 and §5 that this poses serious challenges to a parallel constraint grammar approach).

(20) Monosyllabic, labialized vowel, e.g. /mān-Lhr/→[mùn]

⟦≥ .26 round⟧
V$_1$ → n/a
[+ **round**]

(21) Disyllabic, V1 labialized, e.g. /ɓāgāl-Lhr/→[ɓùgùl]

⟦≥ .26 round⟧ ⟦≥ .26 round⟧
V$_1$ V$_2$ → V$_1$ V$_2$
[+ **round**] [+ **round**]

(22) Disyllabic, V2 labialized, e.g. /tārīm-Lhr/→[tùrùm]

⟦≥ .26 round⟧ ⟦≥ .26 round⟧
V$_1$ V$_2$ → V$_1$ V$_2$
[+ **round**] [+ **round**]

(23) Disyllabic, both vowels labialized, e.g. /pālīm-Lhr/→[pùlùm]

⟦≥ .26 round⟧ ⟦≥ .26 round⟧

V_1 V_2 → n/a

[+ **round**]

Note, finally, that subfeatures are not actual phonetic information (e.g. Hz measurements), but abstract phonetic knowledge, as mentioned earlier. For example, in /ɓāgāl + Ⓛ [+ high + round]/ → [ɓùgùl], it is not the input V1 /a/ that carries the relevant subfeatural value, but the predicted realization [ɨ$^{\mathrm{B}}$] in *[ɓɨ̀$^{\mathrm{B}}$gɨ̀l], which would result from the non-realization of [+ round], all else being equal. In other words, the output form [ɓùgùl] is compared to the purely abstract form [ɓɨ̀$^{\mathrm{B}}$gɨ̀l], which is never realized, i.e. not part of the speaker or hearer's phonetic experience as such, but predicted on the basis of independent phonetic knowledge (e.g. the systematic labialization found in words like /pɨ́r/ → [pɨ́$^{\mathrm{B}}$r] 'catch'). The fully rounded form [ɓùgùl] is deemed more optimal than the non-rounded [ɓɨ̀$^{\mathrm{B}}$gɨ̀l] because the latter fails to realize the floating [+ round] despite the presence of the labialized licensor [ɨ$^{\mathrm{B}}$] of this feature.

4.4 Constraint-based subfeatural account

In this section, I propose a coarticulatorily based analysis of the conditional realization of the floating [+ round] feature, couched in Harmonic Grammar, and making use of subfeatural representations and a scalar weighted constraint.[20] I adopt Lionnet's (2017) implementation of subfeatural representations in constraint grammars, briefly reviewed in § 4.4.1. I then present the basic mechanism of the analysis by applying it to monosyllabic words (§ 4.4.1), and finally describe the challenge posed by disyllabic words, and propose a solution to this challenge (§ 4.4.3).

4.4.1 Enforcing subfeatural specifications in a constraint grammar

Lionnet (2017) proposes that subfeatural distinctions be enforced by the phonological grammar, through undominated markedness constraints. The default ⟦0 F⟧ ↔ [–F] and ⟦1 F⟧ ↔ [+ F] associations are enforced through the constraints defined in (24) and (25), while labial coarticulation is enforced by the constraint in (26).;

(24) *⟦ > 0 F⟧/[–F]

Let X be a vowel; X may not be higher than ⟦0 F⟧ on the subfeatural scale if it is specified as [–F].

(25) *⟦ < 1 rd⟧/[+ F]

Let X be a vowel; X may not be lower than ⟦1 F⟧ on the subfeatural scale if it is specified as [+ F].

[20] For more on scalar constraints, see Frisch, Broe, and Pierrehumbert (1997, 2004), Flemming (2001), Kimper (2011), McPherson and Hayes (2016), Hsu and Jesney (2016, 2017, 2018), McCollum (2018), a.o.

(26) COART(ICULATION)

Coarticulation must take place, i.e. the appropriate value of ⟦*x* F⟧ must be assigned to segments known to coarticulate with neighboring segments according to phonetic knowledge. Assign one violation per segment that meets the requirements but fails to coarticulate.

These constraints are illustrated in the tableaux in (27) with the feature [round] and associated subfeatural values, for non-coarticulated [–round] (a) and [+ round] (b), as well as for labialized [–round] (c), with labialization triggering an increase of the subfeatural value from ⟦0 round⟧ to ⟦x round⟧. Note that COART must be stronger than the two constraints in (24) and (25), if coarticulation-driven subfeatural values are to be assigned. This is shown in (27c), where candidate (ii) wins over candidate (i) only if COART > *⟦>0 F⟧/[–F].

(27)

			COART $w=2$	*⟦>0 F⟧/[–F] $w=1$	*⟦<1 F⟧/[+F] $w=1$	H
a. /ɨ/	☞i.	ɨ ⟦0 rd⟧				0
	ii.	ɨ ⟦x rd⟧		-1		-1
	iii.	ɨ ⟦y rd⟧		-1		-1
	iv.	ɨ ⟦1 rd⟧		-1		-1
b. /u/	i.	u ⟦0 rd⟧			-1	-1
	ii.	u ⟦x rd⟧			-1	-1
	iii.	u ⟦y rd⟧			-1	-1
	☞iv.	u ⟦1 rd⟧				0
c. /Bɨ/	i.	Bɨ ⟦0 rd⟧	-1			-2
	☞ii.	Bɨ ⟦x rd⟧		-1		-1
	iii.	Bɨ ⟦y rd⟧	-1	-1		-3
	iv.	Bɨ ⟦1 rd⟧	-1	-1		-3

As seen in (27), the constraints pick only one of all the possible subfeatural values comprised between 0 and 1 for each input: default 0 or 1 when there is no coarticulation (27a-b), *x* (and not $y \neq x$, or any other intermediate value that does not correspond to the expected coarticulatory effect stored in phonetic knowledge) when coarticulation between a labial consonant and [ɨ] is involved (27c).

In the interest of space, I will henceforth ignore these constraints in tableaux and show only output candidates where they are not violated. See Lionnet (2017) for more detail on the implementation of subfeatural distinctions in constraint grammars.

4.4.2 Faithfulness scaled to subfeatural values

In this section, I develop an analysis of the role of labial coarticulation in the realization of the [+ round] floating feature based on the general idea that coarticulation affects faithfulness. Specifically, faithfulness to coarticulated segments (perceptually ambiguous, less easily recoverable) is weaker than faithfulness to non-coarticulated segments (perceptually non-ambiguous, fully recoverable). In the case of Laal, faithfulness to a [–round] vowel in a non-labializing environment is strong enough to protect it from rounding, thus preventing the realization of the floating [+round]. The same faithfulness is however weakened if the [–round] vowel is in a labializing environment, and cannot protect it anymore against the necessity to realize the floating [+round]. This idea is in keeping with the main intuition underlying Steriade's (2009) P-map (cf. §5 for a comparison of the present proposal and a P-map approach).

To implement this idea, I propose that faithfulness constraints be scaled to the subfeatural value associated with the feature they are meant to protect. Indeed, subfeatures are a direct representation of the speaker's knowledge of coarticulation. Given the analysis proposed in § 3.2.2, the type of constraint needed in the Laal case is MAX$_s$[αF], defined in (28) (this preliminary definition will be refined in § 4.4.3).

(28) MAX$_s$[αF] (first pass):
Given...
- a constraint weight w,
- the subfeatural $[\![x_{o(utput)}\mathrm{F}]\!]$ value associated with a feature [αF] in an output candidate,
- the subfeatural value $[\![x_{p(redicted)}\mathrm{F}]\!]$ associated with the faithful realization of that feature [F] in the same segmental context as can be predicted from phonetic knowledge,
- and a scaling factor $s(x) = |x_o - x_p|$,

...for any output feature value [αF] (associated with a $[\![x_o\mathrm{F}]\!]$ value) corresponding to an input feature value [$-\alpha$F] (whose faithful realization in the same context would be associated with a $[\![x_p\mathrm{F}]\!]$ value), assign a weighted violation score of $w \cdot s(x)$.

MAX$_s$[αF] is scaled to the distance between the subfeatural $[\![x_o\mathrm{F}]\!]$ value of the output segment where the [$-\alpha$F]$\rightarrow$[αF] change has taken place (e.g. $[\![1$ round$]\!]$ in the vowel in [mùn], from input /mān/), and the $[\![x_p\mathrm{F}]\!]$ value that this segment would be associated with according to phonetic knowledge if that featural change had not happened, all else being equal (e.g. $[\![.47$ round$]\!]$ in predicted unrounded [mɨ̀$^{\mathrm{B}}$n]).

The specific constraint at work in Laal is MAX$_s$[–round], and its effect is illustrated in Table 2, with the two monosyllabic inputs */ɗāg-Lhr/ (unattested, cf. Table 1) and /mān-Lhr/.

As can be seen, the penalty incurred by rounding a vowel in a non-labializing environment is greater than that incurred by rounding the same vowel in a labializing environment, i.e. coarticulation weakens faithfulness. The effect of MAX$_s$[–round] is illustrated in the two tableaux in (29) and (30) below. The lesser penalty incurred by the violation of MAX$_s$[–round] in a labial environment allows candidate (30b) [mùn], where the floating [+round] feature is realized, to be optimal. On the other hand, the full penalty incurred by rounding a vowel in a non-labial environment in (29b) prevents the floating feature from being realized, as candidate (29a) [ɗɨ̀g] emerges as optimal. Note that throughout, I assume strong faithfulness to consonants, preventing delabialization, e.g. /ɓ/ $\rightarrow$ [ɗ]. By undoing labialization, this would indeed prevent the floating [+round] from being realized, allowing a form like [nɨ̀n] to be the optimal output of /mān-Lhr/.

Table 2: Penalty incurred by a violation of MAX$_s$[–round] in labial vs. non-labial contexts

	Non-labial environment	Labial environment
Input	*/ɗāg Ⓛ [+hi, +rd]/	/mān Ⓛ [+hi, +rd]/
Output candidate	*[ɗùg] | ⟦$x_o = 1$ rd⟧	[mùn] | ⟦$x_o = 1$ rd⟧
Compared to	*[ɗɨ̀g] | ⟦$x_p = 0$ rd⟧	[mɨ̀ᴮn] | ⟦$x_p = .47$ rd⟧
Scaling factor	$s = \|1 - 0\| = 1$	$s = \|1 - .47\| = .53$
Penalty	$-1 * w * 1$ $-w$ $<$	$-1 * w * .53$ $-.53w$

(29) Non-labial environment:

ɗ ā g | [–rd]	$\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ L	MAX$_s$[–rd] $w = 3$ $s = \|x_o - x_p\|$	MAX[+rd] $w = 2$	H
☞a. ɗ ɨ̀ g | [–rd]			$-1 * 2$	-2
b. ⟦1 rd⟧ | ɗ ù g | [+rd]	⟦0 rd⟧ | ∼ ɗ ɨ̀ g | [–rd]	$-1 * 3 * \|1 - 0\|$		-3

(30) Labial environment:

m ā n | [–rd]	$\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ L	MAX$_s$[–rd] $w = 3$ $s = \|x_o - x_p\|$	MAX[+rd] $w = 2$	H
a. m ɨ̀ᴮ n | [–rd]			$-1 * 2$	-2
☞b. ⟦1 rd⟧ | m ù n | [+rd]	⟦.47 rd⟧ | ∼ m ɨ̀ᴮ n | [–rd]	$-1 * 3 * \|1 - .47\|$		-1.59

4.4.3 Direct vs. segment-mediated feature correspondence

I have so far illustrated the analysis with monosyllabic words only. I now show that accounting for both mono- and disyllabic forms is a challenge for any constraint-based analysis of the Laal data (see also §5). For the subfeatural analysis presented above to work, the overall penalty incurred by violations of the scalar faithfulness constraint FAITH$_s$[αrd] must be greater in */ɗāg-Lhr/ $\rightarrow$ 💣*[ɗùg] than in /ɓāgāl-Lhr/ $\rightarrow$ [ɓùgùl]. This is impossible if FAITH$_s$[αrd] is evaluated on the basis of segment-mediated correspondence, i.e. with IDENT$_s$[αrd].[21] Indeed, rounding both vowels in /ɓāgāl-Lhr/ $\rightarrow$ [ɓùgùl] would incur two violations of IDENT$_s$[αrd]: a weakened violation for the first, labialized vowel, and a full violation for the second, non-labialized one. However, the latter violation is the same as that incurred by rounding the only vowel in */ɗāg-Lhr/ $\rightarrow$ 💣*[ɗùg]. One such violation must thus be sufficient to prevent rounding if one wants *[ɗɨ̀g] to be optimal. Consequently, a constraint weight relation correctly predicting */ɗāg-Lhr/ $\rightarrow$ *[ɗɨ̀g] incorrectly predicts /ɓāgāl-Lhr/ $\rightarrow$ 💣[ɓɨ̀gɨ̀l]. The problem can easily be seen in the penalty strength hierarchy summarized in (31) (💣marks outputs incorrectly predicted to be optimal).

(31) Strength of penalty incurred by violating IDENT$_s$[rd]:

	/ɗāgān-Lhr/	💣[ɗùgùn]	2 full penalties:	$-2w$
>	/ɓāgāl-Lhr/	[ɓùgùl]	1 full + 1 partial penalty:	$-1.53w$
>	*/ɗāg-Lhr/	💣*[ɗùg]	1 full penalty:	$-1w$
>	*/mān-Lhr/	*[mùn]	1 partial penalty:	$-.53w$

As seen, no penalty threshold can be drawn that would separate the rounding cases [ɓùgùl] and [mùn] from the non-rounding ones [ɗɨ̀gɨ̀n] and *[ɗɨ̀g]: a threshold separating rounding [ɓùgùl] from non-rounding *[ɗɨ̀g] wrongly predicts 💣[ɗùgùn] instead of the expected [ɗɨ̀gɨ̀n]; one between non-rounding [ɗɨ̀gɨ̀n] and rounding [ɓùgùl] wrongly predicts 💣*[ɗùg], instead of expected *[ɗɨ̀g]. This is clearly shown by the partial factorial typology of a grammar using the three constraints MAX[+round], MAX[–round], and IDENT$_s$[αrd], presented in Table 3. For clarity and simplicity, this illustrative factorial typology takes into account only candidates with [–front] vowels, where the [+round] feature of the plural affix is either fully realized (grayed cells) or left unrealized, all other subexponents (Ⓛ and [+high]) being realized. As can be seen, it fails to make the correct prediction. [22]

Table 3: MAX[+round], MAX[–round], and IDENT$_s$[αrd]: factorial typology (✓predicted as a possible grammar; ✗ not predicted to be a possible grammar; 💣 wrong predicted output)

		/ɗāgān-Lhr/ $-2w$	/ɓāgāl-Lhr/ $-1.53w$	*/ɗāg-Lhr/ $-1w$	/mān-Lhr/ $-.53w$
✓	Round all:	💣 ɗùgùn	ɓùgùl	💣 ɗùg	mùn
✓	Round all but 2σ&¬LabC:	ɗɨ̀gɨ̀n	ɓùgùl	💣 ɗùg	mùn
✓	Round 1σ only:	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	💣 ɗùg	mùn
✓	Round 1σ&LabC only:	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	ɗɨ̀g	mùn
✓	Round none:	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	ɗɨ̀g	💣 mɨ̀n
✗	Correct prediction:	ɗɨ̀gɨ̀n	ɓùgùl	ɗɨ̀g	mùn

One might think that with featural faithfulness based on unmediated feature correspondence, such as with the MAX[F] constraint family, one would avoid this problem. Indeed MAX[F] is violated only once per feature [F] whose output value differs from its input counterpart, irrespective of how many segments it is associated

[21] For more on the difference between segment-mediated and direct featural correspondence, see Struijke (2002: ch.4), and references therein.

[22] Note that the predictions would be similar if the realization of the floating [+round] were accounted for using other constraints, e.g. MAXFLT: the problem lies with the evaluation of faithfulness through IDENT$_s$[–round].

with. Max$_s$[–rd] is thus violated only once in disyllabic forms like /ɓāgāl-Lhr/ $\rightarrow$ [ɓùgùl], i.e. exactly as many times as in a monosyllabic form like /mān-Lhr/ $\rightarrow$ [mùn], if the [–round] and [+round] features of the input and output respectively are analyzed as multiply linked. However, there is another difficulty here, which is related to the evaluation of the scalar factor s associated with Max$_s$[–rd]. This calculation requires reference to subfeatural values, which can only be determined on a segmental basis, since it refers directly to contextual, co-articulatory effects. For example, in the form [ɓɨ̀ᴮgɨ̀l], although there is only one [–round] feature, associated with both vowels, this feature is not associated with a single subfeatural value, but with two: the $[\![.47 \text{ round}]\!]$ value of the first vowel, and the $[\![0 \text{ round}]\!]$ value of the second one. This asymmetry is a problem for the calculation of the scaling factor s. The only solution to this problem is to calculate the scaling factor on the basis of the average of the subfeatural values borne by all the segments with which the feature [αF] is associated. The scaling factor thus needs to be redefined as follows:

(32) $$s = |\overline{x_o - x_p}| = \frac{1}{n}\sum_{i=1}^{n} |x_{oi} - x_{pi}|$$

With such a definition of the scaling factor, the analysis proposed above, using the scalar constraint Max$_s$[–round], makes the correct predictions, as shown in the two disyllabic examples in Table 4, and the penalty strength scale corresponding to violations of Max$_s$[–round] in (33). Indeed, rounding both vowels in a disyllabic word incurs only one violation of Max$_s$[–round], and this violation systematically results in a lesser penalty if at least one of the two vowels in the word is in a labializing environment.

Table 4: Penalty incurred by a violation of Max$_s$[–round] in labial vs. non-labial contexts

	Non-labial environment		Labial environment
Input:	/ɗāgān-Ⓛ[+hi, +rd]/		/ɓāgāl-Ⓛ[+hi, +rd]/
Output candidate:	$[\![x_{o1} = 1 \text{ rd}]\!]$ $[\![x_{o2} = 1 \text{ rd}]\!]$ [ɗ ù g ù n] [+rd]		$[\![x_{o1} = 1 \text{ rd}]\!]$ $[\![x_{o2} = 1 \text{ rd}]\!]$ [ɓ ù g ù l] [+rd]
Compared to:	$[\![x_{p1} = 0 \text{ rd}]\!]$ $[\![x_{p2} = 0 \text{ rd}]\!]$ [ɗ ɨ̀ g ɨ̀ n] [–rd]		$[\![x_{p1} = .47 \text{ rd}]\!]$ $[\![x_{p2} = 0 \text{ rd}]\!]$ [ɓ ɨ̀ᴮ g ɨ̀ l] [–rd]
Scaling factor:	$s = \frac{\lvert 1-0\rvert + \lvert 1-0\rvert}{2} = 1$		$s = \frac{\lvert 1-.47\rvert + \lvert 1-0\rvert}{2} = .765$
Penalty:	$-1 * w * 1 = -w$	$<$	$-1 * w * .765 = -.765w$

(33) Strength of penalty incurred by violating $\textsc{Max}_s$[rd]:

	/ɗāgān-Lhr/	💣[ɗùgùn]	Full penalty:	$-1w$
	*/ɗāg-Lhr/	💣*[ɗùg]	Full penalty:	$-1w$
>	/ɓāgāl-Lhr/	[ɓùgùl]	Higher partial penalty:	$-.765w$
>	*/mān-Lhr/	*[mùn]	Lower partial penalty:	$-.53w$

As seen from (33), the correct threshold between non-rounding and rounding forms can now be drawn. The effect of the newly defined $\textsc{Max}_s$[–round] is illustrated in tableaux (34) through (37). Notice that constraint weights need to be adjusted compared to tableaux (29) and (30) in § 4.4.2, in order to account for both mono- and disyllabic forms (see Table 6 in § 4.5.4 for more detail).

(34) No labial consonant, one syllable:

ɗ ā g | [–rd] $\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ L	FLT-L&R $w=8$	$\textsc{Max}_s$[–rd] $w=8$ $s=\lvert x_o-x_p\rvert$	MAX[+rd] $w=7$	H
☞a. ɗ ɨ̀ g | [–rd]			$-1*7$ $=-7$	-7
b. ⟦1 rd⟧ ⟦0 rd⟧ | | ɗ ù g ∼ ɗ ɨ̀ g | | [+rd] [–rd]		$-1*8*\frac{\lvert 1-0\rvert}{1}$ $=-8$		-8

(35) No labial consonant, two syllables:

ɗ ā g ā n \/ [–rd] $\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ L	FLT-L&R $w=8$	$\textsc{Max}_s$[rd] $w=8$ $s=\lvert x_o-x_p\rvert$	MAX[+rd] $w=7$	H
☞a. ɗ ɨ̀ g ɨ̀ n \/ [–rd]			$-1*7$ $=-7$	-7
b. ɗ ɨ̀ g ù n | | [–rd][+rd]	$-1*8$ $=-8$			-8
c. ɗ ù g ɨ̀ n | | [+rd][–rd]	$-1*8$ $=-8$			-8
d. ɗ ù g ù n \/ [+rd] ≀ ⟦0 rd⟧ ⟦0 rd⟧ | | ɗ ɨ̀ g ɨ̀ n \/ [–rd]		$-1*8*\frac{\lvert 1-0\rvert+\lvert 1-0\rvert}{2}$ $=-8$		-8

(36) One labial consonant, one syllable:

m ā n | [–rd] $\begin{bmatrix}\text{+hi}\\ \text{+rd}\end{bmatrix}$ L	FLT-L&R $w = 8$	MAX$_s$[–rd] $w = 8$ $s = \lvert x_o - x_p \rvert$	MAX[+rd] $w = 7$	H
a. m ɨ̀ᴮ n | [–rd]			$-1 * 7$ $= -7$	-7
☞b. ⟦1 rd⟧ ⟦.47 rd⟧ | | m ù n ∼ m ɨ̀ᴮ n | | [+rd] [–rd]		$-1 * 8 * \frac{\lvert 1 - .47 \rvert}{1}$ $= -4.24$		-4.24

(37) One labial consonant, two syllables:

ɓ ā g ā l [–rd] $\begin{bmatrix}\text{+hi}\\ \text{+rd}\end{bmatrix}$ L	FLT-L&R $w = 8$	F·MAX$_s$[rd] $w = 8$ $s = \lvert x_o - x_p \rvert$	MAX[+rd] $w = 7$	H
a. ɓ ɨ̀ g ɨ̀ l [–rd]			$-1 * 7$ $= -7$	-7
b. ɓ ɨ̀ g ù l | | [–rd][+rd]	$-1 * 8$ $= -8$			-8
c. ɓ ù g ɨ̀ l | | [+rd][–rd]	$-1 * 8$ $= -8$			-8
☞d. ɓ ù g ù l [+rd] ≀ ⟦.47 rd⟧ ⟦0 rd⟧ | | ɓ ɨ̀ g ɨ̀ l [–rd]		$-1 * 8 * \frac{\lvert 1 - 0 \rvert + \lvert 1 - .47 \rvert}{2}$ $= -6.12$		-6.12

In tableaux (34) and (35), the violation of MAX$_s$[–round] caused by the realization of the floating [+round] incurs a maximal penalty (–8) that is greater than the penalty incurred by not realizing this feature (violation of MAX[+round], –7), making unrounded candidates (34a) *[ɗɨ̀g] and (35a) [ɗɨ̀gɨ̀n] optimal.

In tableaux (36) and (37), on the other hand, violating MAX$_s$[–round] by realizing the floating [+round] feature incurs only a partial penalty (–4.24 and –6.12 respectively), which is less than the penalty incurred by leaving [+round] unrealized (MAX[+round], –7), making rounded candidates (36b) *[mùn] and (37d) [ɓùgùl] optimal. Tableaux for */mɛ̄n-Ⓛ[+high, +round]/ → [mỳn] and /mɛ̄lāg-Ⓛ[+high, +round]/ → [mỳlùg], illustrating rounding of front vowels, are omitted in the interest of space. They would be similar to tableaux (36) and (37), with violation of MAX$_s$[–round] incurring a penalty of –5.92 and –6.96 respectively, both weaker than the penalty incurred by a violation of MAX[+round], thus favoring the realization of the floating [+round], as expected.

Finally, in the disyllabic cases illustrated in tableaux (35) and (37), rounding only one of the two vowels to realize the floating [+ round] feature in candidates b and c incurs a fatal violation (–8) of FLT-L&R, which enforces the replaciveness of the affixal [+ round].[23]

Note that only the subfeatural values of high vowels are relevant here, since the optimal output vowels are systematically [+ high]. The theory predicts that the same calculation is performed when comparing other candidates, e.g. candidate [ɓɔ̀gɔ̀l] vs. predicted [ɓà$^{\mathrm{B}}$gàl], where the subfeatural $[\![x$ round$]\!]$ value of [a$^{\mathrm{B}}$] would be relevant. But none of these predicted candidates will ever be near-optimal (i.e. different from the optimal output by one feature only, as in [ɓɨ̀$^{\mathrm{B}}$gɨ̀l]). Consequently, the analyst need not consider such candidates, and it is not certain that speakers may ever need to have any phonetic knowledge of these forms either.

4.5 Discussion

4.5.1 Conditions for a subfeatural account

As we saw, in order to implement the subfeatural analysis proposed in § 4.4.2 above in a constraint grammar with parallel constraint evaluation, two crucial analytical devices are needed. The first one is featural faithfulness based on direct feature correspondence (“Featural Independence Theory” in Struijke’s (2002: 149) terms), as opposed to segment-mediated featural correspondence (Struijke’s “Featural Attribute Theory”). Indeed, without direct feature correspondence, mono- and disyllabic forms cannot be accounted for by the same grammar. The second crucial theoretical tool is an extension of the theory of subfeatural representations (Lionnet 2017), allowing for the calculation of the average of the subfeatural values associated with all the segments to which a binary feature is linked. The main idea behind this proposal is to allow for an overall, word-level evaluation of the subfeatural realization of the feature [round] in Laal. A form like [ɗɨ̀gɨ̀n] is as unrounded as can be: all of its vowels are $[\![0$ round$]\!]$, i.e. 0% round. Faithfulness to the feature [–round] linked to both vowels in this case is thus strongest, i.e. it is evaluated on the basis of a scaling factor $s = 1$. In a form like [ɓɨ̀$^{\mathrm{B}}$gɨ̀l], on the other hand, the [–round] feature is associated with a 0% round vowel (V2), and with a 47% round vowel (V1). Faithfulness to [–round] is thus weaker, because the feature is, at least partly, associated with a subphonemically rounded segment. Faithfulness in this case is evaluated with a scaling factor calculated on the basis of the subfeatural values of both vowels: $s = (|1 - 0| + |1 - .47|)/2 = .765$.

[23] An alternative account couched in Harmonic Serialism (McCarthy 2000, 2010; McCarthy and Pater 2016) might be thought to solve this problem without having to resort to this average measurement of subfeatural values. Indeed, the realization of the floating [+ round] on disyallbic words would be modeled in two separate steps (first round the labialized vowel /ɓɨ̀gɨ̀l-Lhr/→/ɓùgɨ̀l/, then the non-labialized one /ɓùgɨ̀l/→/ɓùgùl/), similar to the two steps sketched in (20)-(23) in § 4.3. Although this would avoid the cumulativity effect found with the double violation of IDENT$_{s}$ [round] by non-serial /ɓāgāl-Lhr/→[ɓùgùl], it would not solve the fundamental contradiction that rounding a non-labialized vowel is allowed in disyllabic /ɓùgɨ̀l/→✓[ɓùgùl], but not in monosyllabic */ɗɨ̀g/→💣*[ɗùg].

The proposal to rely on direct feature correspondence is not unprecedented, and it has been showed by previous research to be independently needed.[24] The calculation of average subfeatural values, on the other hand, might be seen as a potential weakness of the proposed analysis. Indeed, subfeatures are meant to be a representation of the speaker's knowledge of the realization of features in context, notably in specific segmental contexts. It is thus both a property of features and a property of segments: a property of features as they are realized on specific segments. The idea of associating an average subfeatural value to a multiply linked feature goes against this very idea: what context, what kind of phonetic knowledge would an average subfeatural value of $[\![.235$ round$]\!]$ associated with the [–round] feature in [ɓì^{B}gɪ̀l] represent? However, this is not what I propose in (32). The average value is not an actual subfeatural value associated with the feature [$\pm$round], i.e. it is not stored in phonetic knowledge. It is only calculated on the basis of actual subfeatural values (derived through articulatory and perceptual experience and stored in phonetic knowledge) to evaluate the overall strength of faithfulness to the [–round] feature. In other words, it is a secondary, derived value that exists only in the evaluation of faithfulness through the determination of the scaling factor.

4.5.2 Gradient markedness and markedness reversal

An interesting consequence of the subfeatural analysis is the gradient definition of markedness that it allows for. Indeed, the respective markedness of [+round] and [–round] in Laal is context-dependent. First, it depends on the morpho-phonological stratum. In stratum 2, where rounding harmony is systematic and unconditional (cf. example (12) and surrounding prose) and no case of conditional realization of a floating [+round] feature is attested, [–round] is systematically more marked than [+round], i.e. when in competition, [+round] wins. In stratum 1, where both the realization of the [+round] subexponent of the multifeatural plural affix and rounding harmony (cf. § 4.2) are conditioned by labial coarticulation, the situation is more complex. The markedness hierarchy depends on the coarticulatory context, more specifically on the scaling factor s associated with MAX$_s$[–round], calculated on the basis of subfeatural $[\![x$ round$]\!]$ values. There is a threshold value τ of the scaling factor s beyond which the markedness hierarchy is reversed:

(38) a. [+round] $\rangle$ [–round] if $s < \tau$ ([+round] cannot override [–round])
b. [–round] $\rangle$ [+round] if $s \geq \tau$([+round] must override [–round])

This is what the scalar constraint MAX$_s$[–round] and the weight relation MAX$_s$[–round] $>$ MAX[+round] capture. The combined effects of the weight and scaling factor associated with MAX$_s$[–round] allow any violation of this constraint to incur a greater penalty than a violation of MAX[+round] only if $s < \tau$. In Laal, the threshold τ corresponds to the highest possible value of s with which the floating [+round] subexponent of the plural affix is realized, i.e. $s = .87$, as in /mɛ̄lāg-Ⓛ[+high, +round]/ $\rightarrow$ [mỳlùg], shown in Table 5.

[24] Cf. Lombardi (1995, 1998), McPherson (2017), among others; cf. Struijke (2002: 149–175) for an overview.

Table 5: Subfeatural $[\![x \text{ round}]\!]$ values and scaling factor associated with output [mỳlùg], compared with predicted unrounded [mì^B lɨ̀g]

	2 syllables, 1 labialized [+ front] V
Input:	/mɛ̄lāg-Ⓛ[+ hi, + rd]/
Output candidate:	$[\![x_{o1} = 1 \text{ rd}]\!]$ $[\![x_{o2} = 1 \text{ rd}]\!]$ [m ỳ l ù g] [+ rd]
Compared to:	$[\![x_{p1} = .26 \text{ rd}]\!]$ $[\![x_{p2} = 0 \text{ rd}]\!]$ [m ì^B l ɨ̀ g] [–rd]
Scaling factor:	$s = \frac{\lvert 1 - .26\rvert + \lvert 1 - 0\rvert}{2} = .87$
Penalty:	$-1 * w * 1 = -.87w$

4.5.3 Faithfulness vs. markedness

One might think that an implementation of this idea of markedness reversal using scalar markedness rather than faithfulness constraints, i.e. in this case *[–round]$_s$ rather than MAX$_s$ [–round], would be more straightforward. However, such a markedness approach to the conditional realization of the floating [+ round] fails to account for the Laal data. Indeed, while the unconditional, categorical behavior of the [+ high] and Ⓛ subexponents is very easy to model with the markedness constraints *[–high] > *[+ high] and *M > *L respectively, as shown in (**??**) in § 3.2.2 above, the conditional realization of [+ round] cannot be captured with *[+ round] and *[–round]$_s$, even if the latter is scaled to the subfeatural value of the segment(s) associated to the [–round] feature. Indeed, non-optimal /ɗāgān-Ⓛ[+ high, + round]/→[ɗùgùn] ([+ round] realized despite the absence of labialization) and optimal /ɓāgāl-Ⓛ[+ high, + round]/→[ɓùgùl] ([+ round] realized as expected) violate only *[+ round], which is not scalar. Consequently, both forms will incur the exact same penalty. The scaling factor associated with *[–round]$_s$ cannot help differentiate between these two outputs. It can only help differentiate between optimal [ɗɨ̀gɨ̀n] (stronger penalty) and suboptimal [ɓì^B gɨ̀l] (weaker penalty), but this is irrelevant. Consequently, a grammar using these constraints can only predict either rounding in both forms, or no rounding in either, irrespective of the presence vs. absence of labial coarticulation. Scaling the constraint that the two rounded forms violate, i.e. *[+ round]$_s$, would not help either, since [+ round] vowels are always $[\![1 \text{ round}]\!]$, irrespective of the segmental environment. Indeed, what is at work here is labialization of [–round] vowels, not delabialization of [+ round] vowels. The violation of *[+ round]$_s$ caused by the realization of the floating [+ round] would, once again, incur the same penalty with both [ɗùgùn] and [ɓùgùl].

To evaluate the difference in penalty between the realization of [+ round] in [ɗùgùn] vs. [ɓùgùl], i.e. to determine which one is more costly, it is necessary to refer to the underlying value of the feature (i.e. [–round]) and to the predicted realization of that feature in the relevant environment (labializing vs. non-labializing). This can only be achieved through a faithfulness constraint such as the MAX$_s$[–round] constraint proposed in § 4.4.2. The role of coarticulation in the conditional realization of the [+round] subexponent of the multifeatural plural affix /Ⓛ[+high, +round]/ of Laal thus excludes the possibility to resort to the markedness (*[F]) approach to floating feature realization mentioned in § 3.2.2.

4.5.4 Predictive power of the analysis

Finally, not only can the analysis make the correct predictions, it can, with different constraint weights, predict scalar effects that could be expected to be typologically attested. Indeed, the interplay between constraint weights and the scaling factor makes it possible to establish a subfeatural threshold for rounding, which corresponds to the threshold of markedness reversal τ mentioned in § 4.5.2 above.

The overall weight relation that is necessary to account for the markedness reversal and the replaciveness of the floating feature is the following:

(39) $(w1)$ FLT-L&R, MAX$_s$[–rd] > $(w2)$ MAX[+rd]

The weights in the analysis presented in § 4.4.3 above ($w1 = 8$, $w2 = 7$, $w2/w1$ ration =.87) allow high vowels of any backness specification to be rounded, in words of any length, as long as at least one of the vowels in the word is labialized. This is due to the fact that the threshold τ is set at a relatively high value in Laal (.87), corresponding to words with the least overall labial coarticulation (one labial consonant affecting a [+front] vowel in a disyllabic word, e.g. /mēlāg-Lhr/→[mỳlùg]). Different constraint weight ratios ($w2/w1$) would yield different thresholds, and one could easily imagine pseudo-Laal languages where the threshold would indeed be different. This is seen in the partial factorial typology given in Table 6, presenting six grammars predicted to possible with this set of constraints. The $w2/w1$ weight ratio characteristic of each grammar is followed by an illustration of this ratio with minimal constraint weights (smallest integers corresponding to the ratio), followed by the predicted forms of the four configurations conducive to rounding in Laal, each characterized by a different scaling factor s. The last column represents the [±round] markedness reversal threshold τ corresponding to each constraint grammar in the typology. Note that all the weight relations in the table below prevent rounding in non-labializing environments, i.e. they all predict */ɗāg-Lhr/ → *[ɗìg], */ɗɛ̄g-Lhr/ → *[ɗìg], /ɗāgān-Lhr/ → [ɗìgìn], and */nɛ̄lāg/ → *[nìlìg]. Note also that, for the sake of the demonstration, labial coarticulation and the subfeatural values that represent its effects are based on Laal (cf. § 4.1). Different languages are naturally likely to have different coarticulation grammars, i.e. different subfeatural values for labialized vowels.

The language L1 in table 6 is Laal. L2, with a lower threshold $\tau = .765$, allows for rounding in all but disyllabic words where the only labialized vowel is [+front] (less labialized than a [–front] high vowel, as we saw in Figures 3 and 4 in § 4.1 above). L3, with a slightly lower threshold ($\tau = .74$), predicts rounding only in monosyllabic words with a labial consonant (and disyllabic words where both vowels are labialized, not shown here, e.g. /pālīm/ → [pùlùm] '*Ficus thonningii* (tree

Table 6: Varying threshold values

	$w2/w1$	$w1$	$w2$	/mān-Lhr/ $s = .53$	*/mɛ̄n-Lhr/ $s = .74$	/ɓāgāl-Lhr/ $s = .765$	/mɛ̄lāg-Lhr/ $s = .87$	Threshold
L1:	.88	8	7	mùn	*mỳn	ɓùgùl	mỳlùg	$\tau = .87$
L2:	.86	5	6	mùn	*mỳn	ɓùgùl	mìlɨ̀g	$\tau = .765$
L3:	.75	4	3	mùn	*mỳn	ɓɨ̀gɨ̀l	mìlɨ̀g	$\tau = .74$
L4:	.67	3	2	mùn	*mìn	ɓɨ̀gɨ̀l	mìlɨ̀g	$\tau = .53$
L5:	.48	25	12	mɨ̀n	*mìn	ɓɨ̀gɨ̀l	mìlɨ̀g	$\tau < .53$

sp.)' in Laal). L4 ($\tau = .53$) predicts rounding only in monosyllabic words containing a [–front] labialized vowel (i.e. the coarticulatory effect on front vowels is not sufficient to make them targets of rounding). Finally, L5 predicts no rounding at all: with a threshold $\tau < .53$, the highest subfeatural value, i.e. the strongest labialization effect in the language is not strong enough to reach the threshold beyond which rounding must occur. There is thus no markedness reversal, and [–round] is systematically less marked than [+round], i.e. [+round] can never override [–round].

5 P-map approach

The analysis of the conditional realization of the floating [+round] feature proposed in § 4.4 is rooted in an intuition similar to Steriade's (2009) P-map hypothesis: faithfulness to a feature [αF] in a specific environment depends on the perceptibility of the contrast between [αF] and [$-\alpha$F] in that environment. FAITH[F] is stronger in environments where the [αF] vs. [$-\alpha$F] contrast is more distinctive, and less strong in environments where it is less distinctive, i.e. where [αF] and [$-\alpha$F] sound more similar. The environment considered here is the presence of a labial consonant next to [i] and [ɨ], the effect of which, as demonstrated in § 4.1, is the partial labialization of the vowel, reducing the distinctiveness between partially rounded [–round] [i^{B} ɨ^{B}] and [+round] [y u] respectively.

In the absence of subfeatural representations, and more generally of representations of phonetic knowledge, P-map analyses have to resort to a hierarchy of contextual faithfulness constraints, mirroring the hierarchy of contextual perceptibility effects. For example, the fact that voicing neutralization is more frequent in word-final position (where the voicing contrast is less easily perceptible), than intervocalically (where the contrast is perceptually more salient) can be captured by the following constraint hierarchy.

(40) FAITH[voice]/V__V > FAITH[voice]/V__#

I now show that a P-map account implemented through such faithfulness constraint hierarchies cannot account for the conditional realization of the floating [+round] feature of the Laal multifeatural plural affix. The subfeatural account proposed in § 4.4 is thus the only coarticulation-based analysis that correctly accounts for the Laal data.

The faithfulness hierarchy needed for a P-map account of the Laal data is the following:

(41) FAITH[–round]/¬B > FAITH[–round]/B (B = {B__, __B})

Two types of faithfulness constraints could be used: IDENT[F], enforcing segment-mediated correspondence, or MAX[F], enforcing unmediated featural correspondence, as explained in § 4.4.3. The IDENT[F] approach would require the following constraints:[25]

(42) P-map account, IDENT[F] approach:
- a. MAX[+round]
- b. FLT-L&R
- b. IDENT[–round]/¬B
- c. IDENT[–round]/B

This approach fails, as shown by the fact that no grammar using the four constraints in (42) can account for the Laal pattern. This is shown by the factorial typology in Table 7, which abstracts away from the orthogonal issue of replaciveness: FLT-L&R is excluded, as well as candidates with partial realization of [+round] (e.g. ɓùgɨ̀l), i.e. only non-round and fully rounded candidates are compared (the gray cells indicate realization of the floating [+round]).

Table 7: P-map analysis with IDENT[F] approach: factorial typology (✓ predicted as a possible grammar; ✗ not predicted to be a possible grammar; 💣 wrong predicted output)

	/ɗāgān-PL/	/ɓāgāl-PL/	*ɗāg-PL/	mān-PL/
✓	💣 ɗùgùn	ɓùgùl	💣 ɗùg	mùn
✓	💣 ɗùgùn	💣 ɓɨ̀gɨ̀l	💣 ɗùg	mùn
✓	💣 ɗùgùn	💣 ɓɨ̀gɨ̀l	💣 ɗùg	💣 mɨ̀n
✓	ɗɨ̀gɨ̀n	ɓùgùl	💣 ɗùg	mùn
✓	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	💣 ɗùg	mùn
✓	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	💣 ɗùg	💣 mɨ̀n
✓	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	ɗɨ̀g	mùn
✓	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	ɗɨ̀g	💣 mɨ̀n
✗ (correct)	ɗɨ̀gɨ̀n	ɓùgùl	ɗɨ̀g	mùn

Like in § 4.4.3, there is a contradiction between the weights necessary to account for monosyllabic vs. disyllabic forms. Indeed, it is impossible to enforce rounding of a non-labialized vowel in disyllabic forms with only one labialized vowel, e.g. /ɓāgāl-Lhr/ → [ɓùgùl], without enforcing the realization of the floating [+round] in monosyllabic words with no labialized vowels, e.g. */ɗāg-Lhr/ → 💣*[ɗùg.]. [26] This is clearly shown by two of the possible grammars listed in table 7, repeated as A and B in Table 8).

Grammar A is the only one that makes the correct predictions for monosyllabic forms. It fails to correctly predict rounding in [ɓùgùl] because it allows the two

[25] MAX[–round] is ignored, presumably too weak to have an effect. The factorial typology in Table 7 does not change much if MAX[–round] is included. Using another constraint such as MAXFLT instead of MAX[+round] to account for the realization of [+round] would not change anything.

[26] This amounts to a simple ranking contradiction in classic, strict-ranking OT: IDENT[–round]/¬B ≫ MAX[+round] for monosyllabic forms, vs. MAX[+round] ≫ IDENT[–round]/¬B for disyllabic ones. As shown in this section, this contradiction is not solved in Harmonic Grammar.

Table 8: Weighting contradiction in the P-map account

	/ɗāgān-PL/	/ɓāgāl-PL/	*ɗāg-PL/	mān-PL/
A: (3) ID/¬B > (2) M[+rd] > (1) ID/B	ɗɨ̀gɨ̀n	💣 ɓɨ̀gɨ̀l	ɗɨ̀g	mùn
B: (5) M[+rd] > (3) ID/¬B > (1) ID/B	ɗɨ̀gɨ̀n	ɓùgùl	💣 ɗùg	mùn

contextual IDENT[–round] constraints to gang up on MAX[+round], as shown in candidate h in Tableau (43).

(43)

*/ɗāg-Lhr/	IDENT [–rd]/¬B $w=3$	MAX [+rd] $w=2$	IDENT [–rd]/B $w=1$	H
☞a. ɗɨ̀g		-1		-2
b. ɗùg	-1			-3
/mān-Lhr/				
c. mɨ̀n		-1		-2
☞d. mùn			-1	-1
/ɗāgān-Lhr/				
☞e. ɗɨ̀gɨ̀n		-1		-2
f. ɗùgùn	-2			-6
/ɓāgāl-Lhr/				
💣 g. ɓɨ̀gɨ̀l		-1		-2
☹ h. ɓùgùl	-1		-1	-4

Conversely, grammar B in Table 8 makes the correct predictions for disyllabic forms, but incorrectly enforces rounding in monosyllabic [ɗùg]. As shown in tableau (44), IDENT[–round]/¬B is now too weak to overcome MAX[+round] and prevent the realization of the floating [+round] on 💣*[ɗùg] (candidate b).

(44)

*/ɗāg-Lhr/	MAX [+rd] $w=5$	IDENT [–rd]/¬B $w=3$	IDENT [–rd]/B $w=1$	H
☹ a. ɗɨ̀g	-1			-5
💣 b. ɗùg		-1		-3
/mān-Lhr/				
c. mɨ̀n	-1			-5
☞d. mùn			-1	-1
/ɗāgān-Lhr/				
☞e. ɗɨ̀gɨ̀n	-1			-5
f. ɗùgùn		-2		-6
/ɓāgāl-Lhr/				
☞g. ɓɨ̀gɨ̀l	-1			-5
h. ɓùgùl		-1	-1	-4

Resorting to unmediated feature faithfulness (i.e. MAX[F] constraints only: MAX[–round]/¬B > MAX[–round]/¬B), as I did in the subeatural analysis (§ 4.4.3), does not solve this fatal problem. Indeed, the same issue arises as in the subfeatural approach, i.e. how to establish the relation between a multiply linked feature and the different segmental contexts it is associated with. But this issue is unsolvable within the formalism of the P-map proposed by Steriade (2009). Indeed, in a disyllabic form such as /ɓāgāl-Ⓛ[+high, +round]/ → [ɓùgùl], the output form [ɓùgùl] clearly violates faithfulness to [–round]; but. if [–round] is linked to both vowels, it is impossible to determine which one of Max[–rd]/B or MAX[–rd]/¬B it violates. As we saw, the subfeatural approach does not need to posit two separate faithfulness constraints, but only one scalar MAX_s[–round]. This, combined with the possibility to refer to subfeatural representations, provides a solution to this problem, by allowing the scaling factor affecting MAX_s[–round] to refer to word-level average subfeatural values.

Another advantage of using one scalar faithfulness constraint is that it offers a more intuitive and satisfying implementation of the idea of gradient faithfulness, without the duplication problem posed by multiplying FAITH constraints in a stringency hierarchy. Consequently, not only are subfeatural representations, and reference to them in the evaluation of faithfulness through scalar constraints an expression of the same idea as the P-map, they are a necessary improvement of the P-map, increasing its predictive power and descriptive adequacy.

6 An Agreement by Correspondence based alternative

6.1 Agreement by Correspondence analysis

In this section, I propose and evaluate a radically different alternative, eschewing the need for subfeatural representations and reference to coarticulation altogether. This alternative is couched in Agreement by Correspondence (ABC) theory, originally developed for consonant harmony (Walker 2000, 2001; Hansson 2001, 2010; Rose and Walker 2004), later extended to vowel harmony (Sasa 2009, Walker 2009, 2015; Rhodes 2012, a.o.), consonant dissimilation (Bennett 2013, 2015), or local segmental processes (Inkelas and Shih 2014, Sylak-Glassman 2014).

The central insight of ABC is that (dis)harmony is driven by similarity threshold effects. (Dis)harmony between segments is viewed as (dis)agreement between segments in a correspondence relationship based on phonological similarity. This surface correspondence is unstable, i.e. the segments in correspondence are sufficiently similar to interact, but are too uncomfortably similar to co-exist within a certain domain. Two repairs are possible: harmony (more similarity) and disharmony (less similarity).

Instead of analyzing the floating [+round] in Laal as being conditioned by labial coarticulation, as in the subfeatural account proposed earlier in this paper, one could view it as being driven by featural similarity, or more precisely, as we will see, *potential* featural similarity between labial consonants and vowels. The ABC analysis developed below is a formalization of this idea. In the interest of space, only the conditional realization of [+round] is shown here, i.e. only output forms where the Ⓛ and [+high] subexponents are realized are considered.

Agreement in ABC is driven by the cooperation of two constraints: CORR-XX, enforcing surface correspondence between output segments X similar in a particular feature or set of features, and the output-output correspondence constraint

IDENT-XX-[F], enforcing agreement in the feature [F] between output segments in correspondence. To model agreement in rounding, the constraint we need is IDENT-XX[round], requiring that all segments in correspondence share the same specification for the feature round, and defined in (45).

(45) IDENT-XX[round]:
Segments in correspondence must agree in the feature [±round]. Assign one violation per pair of adjacent segments in the correspondence set that fail to agree in rounding.[27]

The correspondence set that must be defined in order for this analysis to work must include vowels and labial consonants, to the exclusion of any other segment. This seems impossible at first sight, since labial consonants and vowels do not form a natural class. In order to make them a natural class, one could say that they are the only segments ever to be associated with (any value of) the feature [±round]. Indeed, vowels contrast for rounding, so every vowel bears a [±round] feature value, and labial consonants could be considered to be redundantly [+round], while other consonants never have a redundant [+round] or [–round] feature.[28] In such an analysis, vowels and labial consonants thus form the natural class of potential bearers of the feature [+round]: round vowels and labial consonants are [+round] (contrastively for the former, redundantly for the latter), and non-round vowels could become [+round] through rounding, i.e. a simple change of value of their [–round] feature. This natural class is captured by the correspondence constraint in (46):

(46) CORR-XX[±round]
All segments that are associated with (any value of) the feature [±round] must be in correspondence. Assign one violation per pair of adjacent segments that are not in correspondence.

Like in the subfeatural account proposed in § 4.4, MAX[+round] and MAX[–round] account for the realization of the floating [+round], and FLT-L&R accounts for its replaciveness. Resorting to unmediated featural faithfulness allows the analysis to account for both mono- and disyllabic forms, avoiding the problem described in § 4.4.3 and §5 above.

(47) No labial consonant, one syllable

I. */ɗāg/	MAX [–rd] $w = 4$	MAX [+rd] $w = 3$	IDENT-XX(rd) $w = 3$	FLT-L&R $w = 2$	CORR-XX(rd) $w = 2$	H
☞a. ɗāg						0
b. ɗɔ̄g	−1					−4
II. */ɗāg-Lhr/						
☞c. ɗɨ̀g		−1				−3
d. ɗùg	−1					−4

[27] Following Hansson (2007: 402–404), I choose to assess correspondence and agreement on local pairs of segments to avoid the pathological predictions found with global evaluation.
[28] On redundant features, see Stevens, Keyser and Kawasaki (1986).

(48) No labial consonant, two syllables

I. /ɗāgān/	Max [–rd] $w = 4$	Max [+rd] $w = 3$	Ident-XX-[rd] $w = 3$	Flt-L&R $w = 2$	Corr-XX-(rd) $w = 2$	H
a. ɗāgān					-1	-2
☞b. ɗā$_i$gā$_i$n						0
c. ɗā$_i$gɔ̄$_i$n			-1			-3
d. ɗɔ̄$_i$gā$_i$n			-1			-3
e. ɗɔ̄$_i$gɔ̄$_i$n	-1					-4
II. /ɗāgān-Lhr/						
g. ɗɨ̀gɨ̀n		-1			-1	-5
☞h. ɗɨ̀$_i$gɨ̀$_i$n		-1				-3
i. ɗɨ̀$_i$gù$_i$n			-1	-1		-5
j. ɗù$_i$gɨ̀$_i$n			-1	-1		-5
k. ɗù$_i$gù$_i$n	-1					-4

(49) One labial consonant, one syllable

I. /mān/	Max [–rd] $w = 4$	Max [+rd] $w = 3$	Ident-XX-[rd] $w = 3$	Flt-L&R $w = 2$	Corr-XX-(rd) $w = 2$	H
☞a. mān					-1	-2
b. m$_i$ā$_i$n			-1			-3
c. m$_i$ɔ̄$_i$n	-1					-4
d. nān		-1				-3
II. /mān-Lhr/						
e. mɨ̀n		-1			-1	-5
f. m$_i$ɨ̀$_i$n		-1	-1			-6
☞g. m$_i$ù$_i$n	-1					-4
h. nɨ̀n		-2				-6

(50) One labial consonant, two syllables

I. /ɓāgāl/		MAX [–rd] $w=4$	MAX [+rd] $w=3$	IDENT-XX-[rd] $w=3$	FLT-L&R $w=2$	CORR-XX-(rd) $w=2$	H
☞a.	ɓāgāl					-1	-2
b.	ɓ$_i$ā$_i$gā$_i$l			-1			-3
c.	ɓ$_i$ā$_i$gɔ̄$_i$l			-2			-6
d.	ɓ$_i$ɔ̄$_i$gā$_i$l			-1			-3
e.	ɓ$_i$ɔ̄$_i$gɔ̄$_i$l	-1					-4
f.	ɗā$_i$gā$_i$l		-1				-3
II. /ɓāgāl-Lhr/							
g.	ɓɨ̀gɨ̀l		-1			-1	-5
h.	ɓ$_i$ɨ̀$_i$gɨ̀$_i$l		-1	-1			-6
i.	ɓ$_i$ɨ̀$_i$gù$_i$l			-2	-1		-8
j.	ɓ$_i$ù$_i$gɨ̀$_i$l			-1	-1		-5
☞k.	ɓ$_i$ù$_i$gù$_i$l	-1					-4
l.	ɗɨ̂$_i$gɨ̀$_i$l		-2				-6

When there is no disagreeing segments in the input, as in (47-II) */ɗāg-Lhr/and (48-II) /ɗāgān-Lhr/, rounding satisfies MAX[+round] by realizing the floating [+round], but fatally violates weightier MAX[–round], making the unrounded candidate (47-II-c) [ɗɨ̂g] and (48-II-h) [ɗɨ̂$_i$gɨ̀$_i$n] optimal.

When the input contains disagreeing segments (i.e. a labial consonant and unrounded vowels), as in (49-II) /mān-Lhr/ and (50-II) /ɓāgāl-Lhr/, the unrounded candidate (49-II-f) [m$_i$ɨ̀$_i$n] or (50-II-h) [ɓ$_i$ɨ̀$_i$gɨ̀$_i$l] violates both MAX[+round] and IDENT-XX[round], incurring a total penalty of –6. This makes the rounded candidate (49-II-g) [m$_i$ù$_i$n]/(50-II-k) [ɓ$_i$ù$_i$gù$_i$l] optimal, since it violates only MAX[–round], incurring a penalty of only –4. The floating [+round] feature is thus only realized when MAX[+round] and IDENT-XX[round] are able to gang up on MAX[–round]. In other words, rounding is the optimal repair only when it allows to both fix the disagreement issue (satisfying Ident-XX[round]) and realize the floating [+round] (satisfying MAX[+round]). What triggers the realization of the floating [+round] in the ABC account is the disagreement between the labial consonant and adjacent [–round] vowel.

Note that when the floating [+round] feature is absent, the disagreement between the labial consonant and following unrounded vowel (i.e. violation of IDENT-XX[round]) in (49-I) and (50-I) is repaired by canceling the correspondence relation (candidate a optimal in both cases). In other words, it is preferable to fail to correspond rather than to correspond and disagree. If there isn't any disagreement in the correspondence set, as in (48-I), correspondence is not an issue, and is enforced (candidate b optimal). (There is no possible correspondence in (47 */ɗāg/, since there is only one segment associated with a [±round] feature).

6.2 The subfeatural and ABC accounts compared

The goal of the ABC alternative proposed above is twofold: it is meant to be an analysis that 1) is representationally more economic than the subfeatural account, and

2) eschews the need for phonetic grounding, i.e. reference to coarticulation. I show in this section that the ABC account actually fails to improve representational economy, and that the absence of phonetic grounding makes it both less descriptively and less explanatorily adequate.

Both the subfeatural and the ABC analyses require very specific representations that could be deemed non-economic, in that they add to the commonly accepted set of phonological representations. Indeed, as we saw, the ABC analysis crucially needs to establish correspondence between all vowels and labial (and only labial) consonants. Three representational devices are necessary for this to be possible. The first one is the notion of *potential bearer of a feature value [αF]*: the similarity defining the set of corresponding segments among which agreement is enforced must indeed be established on the basis, not of a shared feature value [αF], but on the possibility to bear that specific feature value (in this case [+round]). Formally, this was translated as the fact of being associated with any value of [$\pm$F], e.g., in Laal, all segments associated with either [+round] or [–round] are defined as a natural class, forming a correspondence set. ABC theory thus needs to be expanded to include this very abstract similarity relation. Note that this property is not defined as the possibility to contrast for rounding, otherwise either labial consonants would be excluded (if they bear a redundant [+round]), or all consonants would be included (if both vowels and consonants share the same contrastive place feature [+round], as further discussed below). All that is needed is a specification for [$\pm$round], be it contrastive or redundant. With such a definition, vowels and labial consonants can be considered to form a natural class. Crucially, however, no other segment can be analyzed as associated with either value of the feature [$\pm$round], in particular, non-labial consonants must be defined as not bearing any redundant [–round] (e.g. /k/ is neither [+round] nor [–round]). This must be stipulated, since there is no independent evidence for the presence of a redundant [+round] feature on labial consonants, and the absence of a redundant [–round] on non-labial ones.

The other two representational devices that are needed in the ABC analysis, already mentioned above, are the distinction between *CPlace and VPlace features*, specifically [labial] vs. [$\pm$round] (Ní Chiosáin and Padgett 1993), and that between *contrastive and redundant features* (Stevens et al. 1986). Indeed, if only one contrastive feature [$\pm$round] were used to characterize both round vowels and labial consonants, then all consonants would qualify as 'potential bearers' of the place feature [$\pm$round], since consonants contrast in place, and the correspondence set defined by CORR-XX[$\pm$round] would include all the segments of the language, making the wrong predictions. Cplace [labial] and VPlace [$\pm$round] must thus be stipulated to be different, and [+round] must be defined as contrastive on vowels, but redundant on consonants.[29] The distinction between contrastive and redundant features comes with a further problem. Indeed, the specific use of redundant features necessary here is potentially problematic even for regular redundant feature theory: redundant features are traditionally used to explain enhancement, e.g. contrastive [+back] is enhanced by redundant [+round], i.e. the redundant feature has a phonetic correlate. There does not appear to be a phonetic correlate of the redundant

[29] Note also that the fact that labial consonants and round vowels (or the [+round] feature) pattern together is exactly the kind of arguments used elsewhere to argue in favor of considering labial consonants and round vowels as carrying the same contrastive feature, as opposed to two substantively separate features [labial] and [$\pm$round] (cf. Unified Feature Theory: Clements 1989, Clements and Hume 1995; also Ní Chiosáin and Padgett 1993: 2)

[+ round] borne by labial consonants, since [labial] is sufficient to capture both the phonological place contrast and the phonetic realization of these consonants.

The three representational devices described above thus appear to involve a high degree of stipulation and arbitrariness. They are meant to capture a special relation between labial consonants and vowels, which is straightforwardly explained by the rounding coarticulatory effect of labial consonants on neighboring vowels. Subfeatural representations, which are meant to directly represent such coarticulatory effects, offer a non-arbitrary and non-stipulative alternative that is supported by instrumental evidence.

This alternative involves grounding (aspects of) phonological computation in gradient phonetic information (although the abstract nature of the phonetic knowledge represented by subfeatures allow to maintain a clear separation between phonology and phonetics, simply mediated by phonetic knowledge; cf. Lionnet 2017 for more detail). This could be used as an argument against the subfeatural approach, accused of being very uneconomical by allowing for infinite phonetic representations in phonological theory. There is not enough space here to develop a counterargument to this economy-based critique, addressed in Lionnet (2017). Lionnet's argument relies mostly on the idea that subfeatural representations are, like binary features, emergent (Mielke 2008), and thus expected not to proliferate uncontrollably. There is also an argument to be made against a substance-free approach, which is that the absence of reference to coarticulation leaves the striking phonetic effect described in § 4.1 unexplained, treating what appears to be a non-trivial correlation as purely incidental.

To sum up, the subfeatural and ABC analyses both have strengths and weaknesses. Preference for one over the other can only rest on the precise evaluation of these strengths and weaknesses, and is thus likely to depend largely on theoretical inclinations, and differing conceptions of the relative importance of economy vs. explanatory power. While recognizing that this might encounter well-argued disagreement, I contend that the subfeatural account outperforms the ABC analysis on the following five points. First, it best captures the intuition that coarticulation weakens faithfulness (which the now long P-map literature has shown to be a fruitful analytical concept). It is also strongly supported by phonetic data, which are not accounted for by the ABC analysis. The descriptive and explanatory power of the new subfeatural representations that it uses makes up for the loss in representational economy, as recently shown by their successful application to the analysis of subphonemic teamwork effects (Lionnet 2016, 2017), or the asymmetry among triggers of coronal palatalization (high non-front vowels typologically trigger palatalization only if high front vowels also do; Jang 2018, 2018, 2019). Finally, both approaches are heavily representational, but the phonetically supported and intuitive subfeatural representations rest on more solid grounds than the mostly arbitrary representational distinctions necessary in the ABC account.

7 Conclusion

In this paper, I described and analyzed a typologically rare multifeatural affix attested in the endangered isolate Laal, involving a unique case of conditional feature affixation. I showed that this case adds to our theoretical and typological understanding of featural affixation (McCarthy 1983; Akinlabi 1996; Wolf 2005, 2007;

Trommer 2012; a.o.), by providing one more case of *bona fide* multiple feature affixation, strengthening McPherson's (2017) argument against Trommer's (2012) claim that multiple feature affixation is always reducible to multiple monofeatural morphemes.

I also showed that the realization of the floating [+round] subexponent of the Laal plural affix is conditioned by labial coarticulation, and thus constitutes new evidence for phonetic grounding in phonology, implemented through gradient representations of phonetic knowledge: Lionnet's (2017) subfeatures. I developed an analysis whereby faithfulness to coarticulated segments is weaker than faithfulness to non-coarticulated segments, using a scalar faithfulness constraint of the type $\textsc{Max}_s[\alpha\text{F}]$, scaled to subfeatural values representing coarticulation. This analysis thus adds to the growing literature on weighted constraint grammars and scalar weighted constraints, and provides further evidence that the scaling factor can be phonetically based (cf. Flemming 2001, McCollum 2018, a.o.).

The conditional realization of the floating [+round] subexponent of the Laal multifeatural affix was further shown to pose a serious problem to any constraint-based approach, a consequence of its replacive nature. Any solution to this problem requires (and justifies) the use of direct feature correspondence constraints of the $\textsc{Max}[\alpha\text{F}]$ family (Lombardi 1995, 1998, a.o.), rather than the usual segment-mediated feature correspondence constraints $\textsc{Ident}[\text{F}]$. Several analyses were shown to fail on this issue, including Steriade's P-map (§5) and a Harmonic Serialism implementation (footnote 23). I proposed two possible solutions: one within the subfeatural account, and one in Agreement by Correspondence Theory. The fact that both accounts heavily rely on representations seems to indicate that detailed representations are key, and a purely grammar-driven account impossible. I gave arguments in favor of the phonetically grounded representations involved in the subfeatural account, and against the mostly stipulative representational devices necessary in the Agreement by Correspondence account (mostly distinctions between CPlace and Vplace, and between contrastive and redundant features).

The subfeatural account, through inclusion of subfeatural representations combined with the use of scalar weighted faithfulness constraints, was also shown to both confirm and supersede Steriade's (2009) P-map theory.

Finally, this paper underscores the crucial way in which understudied endangered languages such as Laal can contribute to the development of linguistic theory, and how important documentation projects targeting such languages are for improving our understanding of the human capacity for language (cf. Seifart et al. 2018).

References

Akinlabi, Akinbiyi (1996). "Featural alignment". In: *Journal of Linguistics* 32, pp. 239–289.

Anttila, Arto (1997). "Deriving variation from grammar". In: *Variation, Change, and Phonological Theory*. Ed. by Frans Hinskens, Roeland van Hout, and W. Leo Wetzels. Amsterdam: John Benjamins, pp. 35–68.

Bennett, William G. (2013). "Dissimilation, consonant harmony, and surface correspondence." PhD thesis. New Brunswick, NJ: Rutgers University.

Bennett, Wm G. (2015). *The Phonology of Consonants*. Vol. 147. Cambridge University Press.

Boersma, Paul and David Weenink (2014). *Praat: doing phonetics by computer*. Version 5.4.

Boyeldieu, Pascal (1977). “Éléments pour une phonologie du laal de Gori (Moyen-Chari)”. In: *Etudes phonologiques tchadiennes*. Vol. 63-64. Bibliothèque de la SELAF (Société des Etudes Linguistiques et Anthropologiques de France). Paris, pp. 186–198.

Boyeldieu, Pascal (1982). *Deux Etudes laal: Moyen-Chari, Tchad*. Vol. 29. Marburger Studien zur Afrika- und Asienkunde: Serie A, Afrika. Berlin: Dietrich Reimer.

Boyeldieu, Pascal (1987). “Déterminations directe/indirecte en laal”. In: *La maison du chef et la tête du cabri: des degrés de la détermination nominale dans les langues d’Afrique centrale*. Paris: Libr. Orientaliste Paul Geuthner, pp. 77–87.

Clements, George N. (1989). “The representation of vowel height”. ms. Cornell University.

Clements, George N. and Elizabeth Hume (1995). “The internal organization of speech sounds”. In: *The Handbook of Phonological Theory*. Ed. by John A. Goldsmith. Cambridge, MA, and Oxford, UK: Blackwell, pp. 245–306.

Ettlinger, Marc (2004). “Aspect in Mafa: An intruiging case of featural affixation”. In: *Proceedings of the 40th Annual Meeting of the Chicago Linguistic Society*. Ed. by Nikki Addams et al. Chicago (IL): Chicago Linguistics Society, pp. 73–86.

Flemming, Edward (2001). “Scalar and categorical phenomena in a unified model of phonetics and phonology”. In: *Phonology* 18, pp. 7–44.

Frisch, Stefan A., Janet B. Pierrehumbert, and Michael B. Broe (2004). “Similarity avoidance and the OCP”. In: *Natural Language and Linguistic Theory* 22.1, pp. 179–228.

Frisch, Stefan, Michael Broe, and Janet Pierrehumbert (1997). “Similarity and phonotactics in Arabic”. Evanston, IL. Available as ROA-223 from the Rutgers Optimality Archive.

Fulmer, S. Lee (1991). “Dual-position affixes in Afar: An argument for phonologicallydriven morphology”. In: *The Proceedings of the West Coast Conference on Formal Linguistics 9*. Ed. by Aaron Halpern. Stanford, CA: CSLI, pp. 189–203.

Hansson, Gunnar Ólafur (2001). “Theoretical and Typological Issues in Consonant Harmony”. PhD thesis. Berkeley: University of California, Berkeley.

Hansson, Gunnar Ólafur (2007). “Blocking Effects in Agreement by Correspondence”. In: *Linguistic Inquiry* 38.2, pp. 395–409.

Hansson, Gunnar Ólafur (2010). *Consonant Harmony: Long-Distance Interaction in Phonology*. Vol. 145. University of California Publications in Linguistics. Berkeley, Los Angeles, London: University of California Press.

Hayes, Bruce and Donca Steriade (2004). “Introduction: the phonetic bases of phonological markedness”. In: *Phonetically Based Phonology*. Ed. by Bruce Hayes, Robert Kirchner, and Donca Steriade. Cambridge: CUP, pp. 1–33.

Hsu, Brian and Karen Jesney (2016). “Scalar Positional Markedness and Faithfulness in Harmonic Grammar”. In: *Proceedings of the 51st Annual Meeting of the Chicago Linguistic Society*. Ed. by A. Botinis. Chicago: Chicago Linguistic Society, pp. 241–255.

Hsu, Brian and Karen Jesney (2017). “Loanword Adaptation in Québec French: Evidence for Weighted Scalar Constraints”. In: *Proceedings of the 34th West Coast*

Conference on Formal Linguistics. Ed. by Aaron Kaplan et al. Somerville, MA: Cascadilla, pp. 249–258.

Hsu, Brian and Karen Jesney (2018). "Weighted scalar constraints capture the typology of loanword adaptation". In: *Proceedings of the 2017 Annual Meeting on Phonology*. Ed. by Gillian Gallagher, Maria Gouskova, and Sora Yin. Washington D.C.: Linguistic Society of America.

Inkelas, Sharon (1998). "The theoretical status of morphologically conditioned phonology: a case study dominance effects". In: *Yearbook of morphology (1997)* 35, pp. 121–155.

Inkelas, Sharon, C. Orhan Orgun, and Cheryl Zoll (1997). "The implications of lexical exceptions for the nature of grammar". In: *Derivations and Constraints in Phonology*. Ed. by Iggy Roca. Oxford and New York: Oxford University Press, pp. 393–418.

Inkelas, Sharon and Stephanie Shih (2014). "Unstable surface correspondence as the source of local conspiracies". In: *NELS 44: Proceedings of the 44th Meeting of the North East Linguistic Society*. Ed. by Jyoti Iyer and Leland Kusmer. Vol. 1, pp. 191–204.

Jang, Hayeun (2018a). "Emergent phonological gradience from articulatory synergies: simulations of coronal palatalization". Paper presented at the 2019 meeting of the Lingusitics Society of America, New York City, 5 January 2019.

Jang, Hayeun (2018b). "Tongue tip as a synergy component in vowel articulations". Paper presented at the 7th International Conference on Phonology and Morphology (ICPM 7), Seoul National University, Seoul, Korea, 29 Jun 2018.

Jang, Hayeun (2019). "Articulatory-based subfeatural representations: tongue tip perturbation made by high vowels". Paper presented at the Annual Meeting on Phonology 2018, University of California, San Diego, 5 October 2018.

Jenks, Peter and Sharon Rose (2015). "Mobile object markers in Moro: the role of tone". In: *Language* 91.2, pp. 269–307.

Kewley-Port, Diane (2001). "Vowel formant discrimination II: Effects of stimulus uncertainty, consonantal context, and training." In: *Journal of the Acoustical Society of America* 110, pp. 2141–2155.

Kim, Yuni (2008). "Topics in the phonology and morphology of San Francisco del Mar Huave". PhD thesis. University of California, Berkeley.

Kim, Yuni (2010). "Phonological and morphological conditions on affix order in Huave". In: *Morphology* 20, pp. 133–163.

Kimper, Wendell (2011). "Competing triggers: Transparency and Opacity in Vowel Harmony". PhD thesis. University of Massachussets, Amherst.

Kingston, John and Randy L. Diehl (1994). "Phonetic Knowledge". In: *Language* 70.3, pp. 419–454.

Legendre, Géraldine, Yoshiro Miyata, and Paul Smolensky (1990). "Harmonic Grammar – A Formal Multi-Level Connectionist Theory of Linguistic Wellformedness: An Application". In: *Proceedings of the Twelfth Annual Conference of the Cognitive Science Society*. Cambridge, MA: Lawrence Erlbaum, pp. 884–891.

Lieber, Rochelle (1987). *An integrated theory of autosegmental processes*. Albany: SUNY Press.

Lieber, Rochelle (1992). *Deconstructing Morphology*. Chicago: University of Chicago Press.

Lionnet, Florian (2016). “Subphonemic Teamwork: A Typology and Theory of Cumulative Coarticulatory Effects in Phonology”. PhD thesis. University of California, Berkeley.

Lionnet, Florian (2017). “A theory of subfeatural representations: the case of rounding harmony in Laal”. In: *Phonology* 34.3, pp. 523–564.

Lombardi, Linda (1995). “Why place and voice are different: Constraint-specific alternations and Optimality Theory”. University of Maryland at College Park. Available as ROA-105 from the Rutgers Optimality Archive.

Lombardi, Linda (1998). “Evidence for MaxFeature constraints from Japanese”. Available as ROA-247 from the Rutgers Optimality Archive.

McCarthy, John J. (1983). “A prosodic account of Arabic broken plurals”. In: *Current Trends in African Linguistics*. Ed. by I. Dihoff. Vol. 1. Dordrecht: Foris, pp. 289–320.

McCarthy, John J. (2000). “Harmonic serialism and parallelism”. In: *Proceedings of the North East Linguistics Society 30*. Ed. by Masako Hirotani. Amherst, MA: GLSA Publications, pp. 501–524.

McCarthy, John J., Wendell Kimper, and Kevin Mullin (2010). *Copying prosodic constituents*. Published: Ms. UMass Amherst.

McCarthy, John J. and Joe Pater, eds. (2016). *Harmonic Grammar and Harmonic Serialism*. London: Equinox.

McCarthy, John J. and Alan Prince (1993). “Generalized Alignment”. In: *Yearbook of Morphology*. Ed. by Geert Booij and Jaap van Marle. Dordrecht: Kluwer, pp. 79–153.

McCollum, Adam G. (2018). “Vowel dispersion and Kazakh labial harmony”. In: *Phonology* 35.2, pp. 287–326.

McPherson, Laura (2017). “Multiple feature affixation in Seenku plural formation”. In: *Morphology* 27.2, pp. 217–252.

McPherson, Laura and Bruce Hayes (2016). “Relating application frequency to morphological structure: the case of Tommo So vowel harmony”. In: *Phonology* 33, pp. 125–167.

Mielke, Jeff (2008). *The Emergence of Distinctive Features*. Oxford: Oxford University Press.

Moore, Brian C.J. and Brian R. Glasberg (1983). “Suggested formulae for calculating auditory-filter bandwidths and excitation patterns”. In: *Journal of the Acoustical Society of America* 74, pp. 750–753.

Ní Chiosáin, Máire and Jaye Padgett (1993). “Inherent VPlace”. UC Santa Cruz.

Noyer, Rolf (1994). “Mobile affixes in Huave: Optimality and morphological well-formedness”. In: *The Proceedings of the West Coast Conference on Formal Linguistics 12*. Ed. by Eric Duncan, Donka Farkas, and Philip Spaelti. Stanford, CA: CSLI, pp. 67–82.

Oostendorp, Marc van (2005). “Expressing inflection tonally”. In: *Catalan Journal of Linguistics* 4, pp. 107–127.

Orgun, C. Orhan (1996). “Sign-based Morphology and Phonology, with Special Attention to Optimality Theory”. PhD thesis. University of California, Berkeley.

Pulleyblank, Douglas (1986). *Tone in Lexical Phonology*. Dordrecht: D. Reidel.

Rhodes, Russell (2012). “Vowel Harmony as Agreement by Correspondence”. In: *Annual Report of the UC Berkeley Phonology Lab*, pp. 138–168.

Rolle, Nicholas (2018). “Grammatical tone: Typology and theory”. PhD thesis. University of California, Berkeley.

Rose, Sharon and Rachel Walker (2004). "A typology of consonant agreement as correspondence". In: *Language* 80.3, pp. 475–532.
Rucart, Pierre (2006). "Templates from syntax to morphology: Affix ordering in Qafar". In: *Proceedings of the ISCA Tutorial and Research Workshop on Experimental Linguistics*. Ed. by A. Botinis. Athens: ISCA and the University of Athens, pp. 213–216.
Sande, Hannah (2017). "Process morphology in a realizational theory". In: *Proceedings of the Forty-Seventh Annual Meeting of the North East Linguistic Society*. Ed. by Andrew Lamont and Katerina Tetzloff. Vol. 3. Amherst (MA), pp. 91–104.
Sande, Hannah (2018). "Cross-word morphologically conditioned scalar tone shift in Guébie". In: *Morphology* 28, pp. 253–295.
Sande, Hannah (2019). "Doubly conditioned phonological processes in Cophonologies by Phase". Paper presented at Princeton University, 20 February 2019.
Sande, Hannah and Peter Jenks (2018). "Cophonologies by Phase". In: *NELS 48: Proceedings of the Forty-Eighth Annual Meeting of the North East Linguistic Society*. Ed. by Sherry Hucklebridge and Max Nelson. UMAss, Amherst: GSLA.
Sande, Hannah, Peter Jenks, and Sharon Inkelas (submitted). "Cophonologies by Ph(r)ase".
Sasa, Tomomasa (2009). "Treatment of vowel harmony in Optimality Theory". PhD thesis. University of Iowa.
Seifart, Frank et al. (2018). "Language documentation 25 years on". In: *Language* 94.94, e324–e345. URL: `https://www.linguisticsociety.org/sites/default/files/e05_94.4Seifart_0.pdf` (visited on 11/01/2019).
Smolensky, Paul and Géraldine Legendre (2006). *The Harmonic Mind: From Neural Computation to Optimality-Theoretic Grammar*. Cambridge, MA: MIT Press.
Staubs, Robert et al. (2010). *OT-Help 2.0 Software package*. University of Massachussetts, Amherst.
Steriade, Donca (2009). "The phonology of perceptibility effects: the P-map and its consequences for constraint organization". In: *The Nature of the Word: Studies in Honor of Paul Kiparsky*. MIT Press vols. Published: Ms., MIT, pp. 151–179.
Stevens, Kenneth N., Samuel Jay Keyser, and Haruko Kawasaki (1986). "Toward a phonetic and phonological theory of redundant features". In: *Invariance and Variability in Speech Processes*. Ed. by J. S. Perkell and D. H. Klatt. Hillsdale, New Jersey: Lawrence Erlbaum, pp. 426–449.
Struijke, Caro (2002). *Existential faithfulness: A study of reduplicative TETU, feature movement, and dissimilation*. New York, London: Routledge.
Sylak-Glassman, John (2014). "Deriving natural classes: the phonology and typology of post-velar consonants". PhD thesis. University of California, Berkeley.
Trommer, Jochen (2012). "Constraints on multiple-feature mutation". In: *Work Papers of the Summer Institute of Linguistics, University of North Dakota* Lingua.122, pp. 1182–1192.
Walker, Rachel (2000). "Long-distance consonantal identity effects". In: *Proceedings of the Nineteenth West Coast Conference on Formal Linguistics (WCCFL 19)*. Ed. by Roger Billerey and Brook Danielle Lillehaugen. Somerville, MA: Cascadilla Press, pp. 532–545.
Walker, Rachel (2001). "Consonantal correspondence". In: *Proceedings of the Workshop on the Lexicon in Phonetics and Phonology: Papers in Experimental and Theoretical Lingusitics*. Workshop on the Lexicon in Phonetics and Phonology: Papers

in Experimental and Theoretical Lingusitics. Vol. 6. Edmonton: University of Alberta Department of Linguistics, pp. 73–84.
Walker, Rachel (2009). “Similarity-sensitive blocking and transparency in Menominee”. In: 83rd Annual Meeting of the Lingusitic Society of America. San Francisco, California.
Walker, Rachel (2015). “Surface correspondence and discrete harmony triggers”. In: *Proceedings of the Annual Meeting on Phonology 2014*.
Welmers, William (1973). *African Language Structures*. Berkeley: University of California Press.
Wiese, R. (1994). “Phonological vs. morphological rules: on German umlaut and ablaut”. In: *Journal of Linguistics* 32, pp. 113–135.
Wolf, Matthew (2005). “An Autosegmental Theory of Quirky Mutations”. In: *Proceedings of WCCFL 24*. Ed. by John Alderete, Chung-hye Han, and Alexei Kochetov, pp. 370–378.
Wolf, Matthew (2007). “For an autosegmental theory of mutation”. In: *UMOP 32: Papers in Optimality Theory III*. Ed. by Leah Bateman et al. Vol. 239–258. Amherst, MA: GLSA.
Yip, Moira (1980). “The Tonal Phonology of Chinese”. Published by Garland Press, New York, 1991. PhD thesis. Cambridge, MA: MIT.

Appendix A [i], [i^{B}], and [y] words used in the instrumental study

Vowel	Word		#
[i]	cíd	‘eat without sauce’	3
	cìl	‘fish sp.’	2
	dig	‘carry, transport’	5
	ɗīn	‘swim’	5
	jí	‘press’	1
	jíl	‘push’	4
	jín	‘to boil (tr.)’	2
	ɟí	‘I (f)’	1
	ɟì	‘to plant (+Obj)’	10
	ɟī	‘to plant’	1
	ɟīn	‘bathe’	2
	ɲìn	‘penis’	2
	sí	‘take (pl)’	2
	tī	‘to dry in sun’	1
	ʔí	‘take (pl)’	3
[i^{B}]	bìl	‘monitor lizard’	4
	bīn	‘jump’	5
	bìr	‘fish trap sp.’	3
	bìr	‘wipe’	4
	ɓí	‘bury’	2
	ɓír	‘count, show’	8
	mīg	‘big male specimen (baboon)’	11
	mín	‘ask’	3
	pǐ	‘flower’	6
	pí	‘blossom / spit’	9
	píg	‘tie’	2
	píl	‘sweat’	2
[y]	by̌ːr	‘fish sp. (pl)’	4
	bỳrùg	‘be broad (pl)’	2
	ɓýràn	‘count them (nt)’	1
	dỳgán	‘transport you (sg)’	2
	dỳgùn	‘transport her’	2
	jūsā	‘have diarrhea (sg)’	1
	jūsāl	‘diarrhea’	3
	mýːnàn	‘dry them (nt)’	3
	mỳlùg	‘be red (pl)’	4
	mỳ… (mỳlùg)	‘be red (pl)’	1
	ndỳːlùn	‘pinch her’	1
	nỳːràn	‘heat them up (nt)’	2
	pỳːr	‘plant sp. (pl)’	11
	pýːràn	‘roll them (nt)’	2
	pýgàn	‘tie them (nt)’	4
	yūs	‘have diarrhea (pl)’	2

Appendix B Full tableaux (/ɗāgān-PL/ and /ɓāgāl-PL/ only)

(51) /ɗāgān/ → [ɗɨ̀gɨ̀n]: L and [+high] realized, [+round] non-realized

	ɗ ā g ā n / M ; $\begin{bmatrix}\text{+hi}\\ \text{+rd}\end{bmatrix}$ L	FLT-L&R $w=8$	MAX$_s$ [–rd] $w=8$ $s=\lvert\overline{x_o-x_p}\rvert$	MAX L $w=7$	MAX [+hi] $w=7$	MAX [+rd] $w=7$	MAX [–hi] $w=1$	MAX M $w=1$	H
a.	ɗāgān			−1	−1	−1			−21
b.	ɗāgɨ̄n	−1		−1		−1			−22
c.	ɗɨ̄gɨ̄n			−1		−1	−1		−15
d.	ɗāgàn	−1			−1	−1			−22
e.	ɗāgɨ̀n	−2				−1			−23
f.	ɗɨ̄gɨ̀n	−1				−1	−1		−16
g.	ɗàgàn				−1	−1		−1	−15
h.	ɗàgɨ̀n	−1				−1		−1	−16
☞i.	ɗɨ̀gɨ̀n					−1	−1	−1	−9
k.	ɗāgūn	−2		−1					−23
l.	ɗɨ̄gūn	−1		−1			−1		−16
m.	ɗūgūn		$-1(\times 8\times 1)$	−1			−1		−16
n.	ɗāgùn	−3							−24
o.	ɗɨ̄gùn	−2					−1		−17
p.	ɗūgùn	−1	$-1(\times 8\times 1)$				−1		−17
q.	ɗàgùn	−2						−1	−17
r.	ɗɨ̀gùn	−1					−1	−1	−10
s.	ɗùgɨ̀n	−1					−1	−1	−10
t.	ɗùgùn		$-1(\times 8\times 1)$				−1	−1	−10

(52) /ɓāgāl/ → [ɓùgùl]: L, [+high], and [+round] realized

ɓ ā g ā l M	$\begin{bmatrix}+\text{hi}\\+\text{rd}\end{bmatrix}$ L	FLT-L&R $w = 8$	MAX$_s$ [–rd] $w = 8$ $s = \lvert x_o - x_p \rvert$	MAX L $w = 7$	MAX [+hi] $w = 7$	MAX [+rd] $w = 7$	MAX M $w = 1$	MAX [–hi] $w = 1$	H
a.	ɓāgāl			−1	−1	−1			−21
b.	ɓāgɨ̄l	−1		−1		−1			−22
c.	ɓɨ̄gɨ̄l			−1		−1		−1	−15
d.	ɓāgàl	−1			−1	−1			−22
e.	ɓāgɨ̀l	−2				−1			−23
f.	ɓɨ̄gɨ̀l	−1				−1		−1	−16
g.	ɓàgàl				−1	−1	−1		−15
h.	ɓàgɨ̀l	−1				−1	−1		−16
i.	ɓɨ̀gɨ̀l					−1	−1	−1	−9
k.	ɓāgūl	−2		−1					−23
l.	ɓɨ̄gūl	−1		−1				−1	−14.12
m.	ɓūgūl		−1(×8 × .765)	−1				−1	−16
n.	ɓāgùl	−3							−24
o.	ɓɨ̄gùl	−2						−1	−17
p.	ɓūgùl	−1	−1(×8 × .765)					−1	−15.12
q.	ɓàgùl	−2					−1		−17
r.	ɓɨ̀gùl	−1					−1	−1	−10
s.	ɓùgɨ̀l	−1					−1	−1	−10
☞t.	ɓùgùl		−1(×8 × .765)				−1	−1	−8.12

Appendix C An exceptional replacive M-tone

The Max-L > Max-M analysis presented above stumbles upon a major obstacle: despite abundance evidence that M is more marked than L in laal, the also exists a replacive suffixal M-tone. This M-tone is one of the subexponents of the resultative passive suffix /-Vl$^{\text{M}}$/ (V is realized as a copy of the root vowel), and is realized on all TBUs in the derived form, as can be seen in (53).

(53)	/ráb/ + /-Vl$^{\text{M}}$/	→	[rābāl]	'be folded'
	/ɟūm/ + /-Vl$^{\text{M}}$/	→	[ɟūmūl]	'be pounded'
	/lòb/ + /-Vl$^{\text{M}}$/	→	[lōbōl]	'be wet'
	/sə̌ɲ/ + /-Vl$^{\text{M}}$/	→	[sə̄ɲə̄l]	'be fought (e.g. war)'

There is evidence that this replacive M tone is better analyzed as underlyingly floating, rather than linked to the segmental subexponent. There are indeed two types of toned suffixes (i.e. suffixes with both segmental and tonal material) in Laal: those whose tone is replacive, and those whose tone is not replacive. I analyze the replacive-toned suffixes as involving a floating tone, i.e. a tonal subexponent not associated with the segmental subexponent in the underlying form, while the non-replacive toned suffixes involve an underlyingly docked tone. This difference is illustrated in (54) with the minimal pair consisting of the ventive suffix /-V̀/, with an underlyingly docked L-toned, and the gerund suffix /-V$^{\text{L}}$/, with a floating L tone.

(54)				Ventive /-V̀/	Gerund /-V$^{\text{L}}$/
	a.	kár	'put'	kár-á (< *kár-à, cf. (55a))	kàr-à
	b.	dāg	'drag'	dàg-à (< *dāg-à, M→L, cf. (14))	dàg-à
	c.	jàr	'cut'	jàr-à	jàr-à

As can be seen, the ventive and gerund suffixes behave differently. They are realized in exactly the same way when combined with M-toned and L-toned roots (54b-c), but when added to a H-toned root, however, their realizations differ: all H for the ventive, all L for the gerund. In general, the gerund suffix imposes a L tone to the entire verb form, irrespective of the underlying tone of the verb: its L-tone is clearly replacive. The L-tone of the ventive suffix, on the other hand, not only does not spread onto the root, but is even replaced by the H tone of the root in (54a), by virtue of a regular H-tone-spread rule whereby the H tone a verb root spreads onto a following L-toned derivational suffix, delinking its L-tone. The replaciveness of the L-tone of the gerund suffix protects it from this H-tone spread. This crucial difference between the two suffixes is illustrated in (54).

(55) a. /kár-V̀/ → k a r - V → [kárá] 'put-VEN'
H L

b. /kár-V$^{\text{L}}$/ → k a r - V → [kàrà] 'put-GER'
H L

The identity of behavior of the two suffixes after M-toned roots in (54b) is only apparent: The floating Ⓛ of the gerund suffix in /dāg-VⓁ/ replaces the M tone of the root, while the presence of a L-tone on the ventive suffix in /dāg-V̀/ triggers the application of the independently attested M-tone lowering rule mentioned above (cf. (14) above).

The criterion used to determine whether a suffixal tone is underlyingly floating or docked is its replaciveness: a replacive affixal feature is floating, a non-replacive one is docked. This is not just a convenient representation accounting for two types of suffixal tonal behaviors, it is actually justified by the independent fact that all purely floating affixal features and tones (i.e. unassociated with segmental material) are replacive in Laal. This representational distinction thus establishes a one-to-one correlation between the replaciveness of features (and tones) and their floating status, and thus offers a simple and unified account of replacive tone in Laal: all suffixal floating tones are replacive, irrespective of whether they are the sole exponent or one of the subexponents of their morpheme, and irrespective of the possible co-occurrence of a segmental subexponent.

According to this analysis, the resultative-passive suffix must be analyzed as involving a floating M-tone: /-VlⓂ/. This poses a problem to the purely phonological (Max[F]-driven) account of the realization of replacive features and tones in Laal proposed in §3 and § 4.4. Indeed, such an account leads to a constraint weighting contradiction similar to that identified in Nuer by Trommer (2012), mentioned above: the plural affix /Ⓛ [+high, +round]/ requires *M > *L, or Max-L > Max-M, while the resultative-passive suffix /-VlⓂ/ requires the opposite.

One could think of at least three possible solutions to this problem, only two of which will are shown to work below. The first option would be to analyze the M tone in Laal as default, i.e. underlyingly $\emptyset$, filled by default M-insertion (as in Pulleyblank's (1986) analysis of Yoruba). This could seem to be warranted by the fact that M is the weakest of all three tones in Laal, as shown earlier (cf. (14), fn. 13). In this case, the resultative-passive suffix would have to be analyzed as underlyingly toneless and tonally subtractive (a case of what Rolle (2018) calls "subtractive-dominant" grammatical tone), i.e. /-Vl/ erases the tonal specification of the root, and the resulting verb form then gets assigned default M: /lób-Vl/ → lob-ol → [lōbōl]. Analyzing M as default in Laal would however fail to account for the M→L rule illustrated in (14) above, specifically in cases where this rule is triggered by a H-toned suffix (14c), since in such cases the surface L tone on the root cannot be explained through spreading from the suffix (short of analyzing every H-toned suffix as being preceded by a floating L tone, which is both *ad hoc* and uneconomic). If there is a rule targeting M tones, those M tones must be underlyingly present.

The second possibility is to resort to an additional constraint enforcing the realization of marked floating material despite markedness-hierarchy enforcing constraints. This is the solution adopted by McPherson (2017) to solve a similar problem in Seenku, where the plural suffix, exponed by the two features [+raised] and [+front], requires Max[+raised] > Max[–raised], while the perfective suffix, exponed by the floating feature [–raised], requires the reverse ranking. McPherson (2017) shows that it is possible to salvage the Max[F] analysis of the realization of the Seenku multifeatural plural affix whereby [+raised] is less marked than [–raised] (Max[+raised] ≫ Max[+raised]), by resorting to high-ranked Realize-Morpheme, which takes care of enforcing the realization of the monofeatural [–

raised] perfective suffix despite the fact that it is less protected by faithfulness than the base feature it overwrites. This solution works in Seenku because the perfective suffix consists of only one feature. Realize-Morpheme is thus both necessary and sufficient to enforce the realization of the floating suffix in its entirety. However, it cannot be applied to the Laal case, since the resultative-passive suffix /-VlⓂ/ is composed of two subexponents. Realizing only the segmental part of the affix and leaving the M tone unrealized would be sufficient to satisfy Realize-Morpheme. This is shown in the tableau in (56), where the form where the affixal M is unrealized (candidate a) does not violate Realize-Morpheme, which allows it to emerge as the optimal output, to the detriment of expected candidate c.[30]

(56) Realize-Morpheme fails to account for /lòb-VlⓂ/ → [lōbōl]

/l ò b -Vl/ L Ⓜ	Flt-L&R $w = 3$	Realize-Morph $w = 2$	Max-L $w = 2$	Max-M $w = 1$	H
☞a. l ò b ò l L				-1	-1
b. l ò b ō l L Ⓜ	-1				-3
☹ c. l ō b ō l Ⓜ			-1		-2

The impossibility for Realize-Morpheme to account for multiple-feature affixation is what prompted Wolf (2005, 2007) to propose a specific MaxFlt constraint, penalizing the non-realization of floating features, irrespective of their markedness status. The MaxFlt approach is the only one of the four approaches to floating feature realization reviewed in § 3.2.2 that accounts for the realization of the replacive M-tone of the resultative-passive suffix /-VlⓂ/. This is shown in the partial tableau in (57) below.

[30] If candidate a did violate Realize-Morpheme, this constraint would gang up with Max-M against Max-L and allow candidate c in (56) to emerge as optimal.

(57) MaxFlt approach to the realization of M in /lōb-Vl$^{Ⓜ}$/

/l ò b -Vl/ L Ⓜ	MaxFlt $w = 3$	Flt-L&R $w = 2$	Ident Tone $w = 1$	H
a. l ò b ò l L	−1			−3
b. l ò b ō l L Ⓜ		−1	−1	−3
☞c. l ō b ō l Ⓜ			−2	−1

If MaxFlt is necessary to account for the realization of the floating M tone of the resultative passive, then it renders Max[F] constraints obsolete. Indeed, the realization of any floating feature or tone is entirely accounted for by MaxFlt, making Max[F] redundant. However, there is evidence for that Max[F] constraints are independently needed to account for the Laal data. First, we saw in **??** that there is strong evidence for the following markedness asymmetries: M ⟩ {L, H}, [–high] ⟩ [+high], [–round] ⟩ [+round]), at work in alternations unrelated to multifeatural affixation and for which Max[F] constraints are be needed (e.g. M-lowering illustrated in (14)). Additionally, I showed in § 4.4.3 that in order to account for the subphonemically conditioned realization of the [+round] subexponent, it is crucial that featural faithfulness be evaluated through unmediated featural correspondence (i.e. Max[F], more specifically scaled Max_s[–round]) rather than segmented-mediated correspondence (Ident[F]). This is true of both the subfeatural approach developed in §§ 3 and 4 and the ABC analysis considered in § 6.1. It thus appears that both Max[F] and MaxFlt are necessary, the former to account for markedness asymmetries and most cases of featural/tonal affixation (including the three features of the multifeatural plural affix), the latter to enforce featural affixation even in cases violating the regular markedness hierarchy of the language (e.g. the replacive M-tone of the resultative-passive suffix). It captures the intuition that specific markedness hierarchies are at wirk in the language (e.g. M ⟩ {L, H} or [+high] ⟩ [–high] in Laal), but that realizing floating material is more important than obeying those markedness hierarchies.

The third solution would be to treat the replacive M of the resultative-passive suffix /-Vl$^{Ⓜ}$/ as exceptional, e.g. as constituting its own morpheme-specific cophonology (cf. Orgun 1996; Inkelas et al 1997; Inkelas 1998; Anttila 1997; and more recently Cophonologies by Phase theory: Sande and Jenks 2018, Sande 2019, Sande et al. submitted). In this specific cophonology, the weight of Max-M is increased by 7, reversing the weight relation between the two Max-T constraints (now (8) Max-M > (7) Max-L), thus enforcing exceptional realization of M only for this specific marker (for the notion of cophonology-specific weight readjustment in Harmonic Grammar, see in particular Sande 2019, Sande et al. submitted). The advantage of this analysis would be to do away with the MAXFLT constraint, and the redundance between MAXFLT and MAX[F].

Whatever analysis one ends up adopting, the replacive M-tone of the resultative passive suffix has to be treated as exceptional, since it contradicts an independently established markedness hierarchy that is clearly at work elsewhere in the language. Ultimately, the analysis of this replacive M-tone is orthogonal to the main point of this paper: the conditional realization of the floating [+round].