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12

The interaction of tone, sonority, and prosodic structure

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12.1 Introduction

The aim of this chapter is to link the major aspects of suprasegmental phonology discussed in this part of the *Handbook* (i.e. tone – Yip Ch.10, Gussenhoven Ch.11; sonority – Zec Ch.8; prosodic structure – Zec Ch.8, Kager Ch.9). It shows how sonority and tone can both influence and be influenced by prosodic structure. It argues that there is a unifying theoretical mechanism that accounts for such influences and how this same mechanism accounts for interactions at all prosodic levels, from below the syllable to the Utterance. To illustrate the theoretical points, the initial empirical focus will be on the influence that sonority can have on foot structure, often called 'sonority-driven stress'. Relevant data from the North New Guinea language Takia are provided in (1).

(1) *Takia sonority-driven stress (Ross 2002, 2003)*

(a) Stress the rightmost syllable with [a]

[taˈma-n]	'father {3sg}'	[araˈtam]	'you (pl.) bite us'
[ŋiˈsaŋes]	'hawk'	[ˈŋa-sol]	'1sg-flee'
[ˈabi]	'garden'	[buguˈgaru]	'twins'

(b) Otherwise stress the rightmost syllable with [e] or [o]

[kirˈŋen]	'her/his finger, toe'	[ŋiˈemi]	'your (pl.) legs/feet'
[ifuˈno]	's/he hit you'	[mulˈmol]	'a kind of tree'

(c) Otherwise stress the rightmost syllable

[ifiˈni]	's/he hit him'	[tuˈbun]	'her/his grandparent'

As with other stress systems, edge-attraction is evident (Kager Ch.9): in a word where all vowels are the same, stress is attracted to the right edge (e.g. [ara'tam], [ifi'ni], [tu'bun]). However, the most important factor for Takia is sonority: stress must fall on the most sonorous vowel available, where the part of the sonority scale that is relevant for Takia is | a ⟩ e,o ⟩ i,u | (for details on sonority, see Section 12.2). The sonority requirements also override conditions on foot form: while [(ta'man)] has an iambic (right-headed) foot, [('abi)] has a trochaic one in order to have a higher sonority foot head.

Section 12.2 identifies several competing theories that aim to account for the interaction seen in Takia and others like it. It argues that recent approaches that derive constraints from markedness hierarchies in a restrictive fashion can account for the observed patterns with sonority and stress (Kenstowicz 1997/2004, de Lacy 2004); it contrasts this approach with ones that employ representational devices (e.g. distinctions in mora count, featural impoverishment).

Section 12.3 identifies analogous influences between sonority and unstressed positions, demonstrating the generality of the interaction between prosodic structure and sonority. The constraint-based proposal is extended to tone-prosody interactions in Section 12.4, different prosodic levels in Section 12.5, and Section 12.6 shows that it can also account for tone– and sonority–prosody interactions involving metathesis, deletion, epenthesis, and neutralization.

This chapter links a number of traditionally distinct areas of research. It discusses markedness and its formal expression: sonority- and tone-driven stress are transparently sensitive to markedness hierarchies, unlike many segmental phenomena (Rice 4.6, de Lacy 2006). It is also a crucial complement to metrical stress theory (Kager Ch.9) since it is not possible to fully account for influences on foot form without considering sonority and tone. Non-metrical stress also provides a link to syllable theory. As Zec (Ch.8) shows, sonority plays a crucial role in the formation of syllables, and the same principles are relevant in foot formation. Finally, tone-driven stress provides insight into how tone and prosodic structure interact, relating to research on both tone (Yip Ch.10) and intonation (Gussenhoven Ch.11).

To give a brief overview of the current state of research in this area, some aspects of the interaction of tone and sonority with prosodic structure have a large literature behind them while others do not. While a great deal has been written about the influence of edges and moraic content on foot structure (see Kager Ch.9), work on sonority- and tone-driven stress is extremely limited in comparison (see the overviews for sonority in Section 12.2, and for tone: de Lacy 2002b). Other related phenomena, such as sonority-driven deletion, also do not have a large literature (see Gouskova 2003 and references cited therein). In contrast, there has been a large amount of research into sonority-driven neutralization (also called ‘vowel reduction’ or ‘raising’) (see Crosswhite 1999, 2004 and references cited therein). A great deal has also been written about metrical influences on tone, forcing tone shift, deletion, neutralization, and so on (see Goldsmith 1987, Downing 1990, Yip 2002, Sec.3.9, 10.3–4 for overviews). Despite the various approaches and different amounts of research on these topics, it is clear that they are currently converging in a theoretical sense. This chapter aims to illustrate the convergence: the same theoretical devices can be used to provide an account of all these disparate phenomena.[1]

12.2 Sonority and prosodic position

The aim of this section is to provide an analysis of Takia's sonority-driven stress system. In doing so, two major theoretical approaches will be identified: (a) constraint-based and (b) representational. These approaches will be evaluated and their typological predictions examined.

By way of general theoretical background, both of the most recent theories of sonority-driven stress (Kenstowicz 1997/2004, de Lacy 2002a, 2004, 2006) advocate the use of constraint interaction as a means of explanation. The idea that constraint interaction can be used to account for sonority-driven stress is proposed in Kenstowicz (1997/2004), who advocates a fixed hierarchy of foot-head and non-head constraints. Kenstowicz' theory relates directly to Prince & Smolensky's (2004) proposal about fixed ranking and the influence of sonority on syllable structure (see Zec 8.5). Building on this approach, the recent alternative advocated by Prince (1997, 1998, 2000, 2001) and de Lacy (2002a, 2004, 2006) is to rely on constraint form entirely and avoid positing universally fixed rankings. Both of these approaches will be discussed below. Theories that use representational devices will also be examined in Section 12.2.3, including those by Hayes (1995:Ch.7), building on proposals by Everett & Everett (1984), Davis (1988b) and Everett (1988).

12.2.1 Sensitivity through stringent constraint form

This section develops an analysis of Takia's stress system. All the data discussed in this section, and the core analytical insight that Takia vowel quality influences stress, are from Ross (2002, 2003). The following discussion focuses on the assignment of primary stress only; Takia has a number of other interesting phenomena that interact with the phenomena discussed here.

Takia has five vowels [a e o i u] and a syllable structure of (C)V(C), though closed syllables are reportedly rare in non-final position. The default position for stress in Takia is on the rightmost syllable. This is evident in words where all vowels have the same sonority level: [ara'tam] 'you (pl.) bite us', [ifi'ni] 's/he hit him', [tu'bun] 'her/his grandparent'. This pattern is the result of requiring right-headed feet ('iambs') to be aligned with the right edge of the Prosodic Word (PrWd); the relevant constraints are in (2) (after McCarthy & Prince 1993a, see Kager 9.3).

(2) *ALIGN-R(Ft, PrWd)*
"The right edge of every foot must coincide with the right edge of a PrWd."
IAMB
"The head of every foot must be rightmost" (i.e. ALIGN-R($\mathrm{Hd}_{\mathrm{Ft}}$,Ft))

Sonority

Takia's stress system is governed by a number of conflicting requirements. One involves 'sonority', which refers to a hierarchy of segment types; the vocalic portion is given in (3), adapted from Kenstowicz (1997/2004) and de Lacy (2006).[2] The exact number of sonority distinctions and their phonetic basis (if there is any) is a very contentious issue: see Parker (2002) for a comprehensive overview. The distinctions given here are needed to account for the range of sonority-driven stress systems identified in Section 12.2.2.[3] (See Section 12.2.2 for discussion of whether sonority can be decomposed into sub-hierarchies and which other features can influence prosodic structure.)

(3) *Vowel Sonority Hierarchy*

low peripheral vowels		mid peripheral vowels		high peripheral vowels		mid central vowels		high central vowels
'*a*'	>	'*e•o*'	>	'*i•u*'	>	'*ə*'	>	'*ɨ*'

Representative vowels are given for each category and will be used as abbreviations for the categories in the rest of this chapter. Of course, many more vowels belong to the categories than the abbreviations suggest; for example, 'high peripheral vowels' includes [y ɯ] as well as [i u]. For discussion about whether hierarchies other than or instead of sonority can influence foot placement, see Section 12.2.2.

Optimality Theory provides the means to formally express the sonority hierarchy in (3) through the form of constraints, as in (4). Because these constraints are in a subset-relation in terms of their violation marks, they are in a 'stringency' relation (Prince 1998 et seq.). This general approach to expressing markedness hierarchies is called 'Stringent Markedness'.[4]

(4) *Stringent sonority constraints (Prince 1998, de Lacy 2002a, 2004, 2006)*

(a) $^*\mathrm{Hd}_\alpha$/*ɨ* "Incur a violation for every head of constituent α that contains a high central vowel"
(b) $^*\mathrm{Hd}_\alpha$/*ɨ,ə* "Incur a violation for every head of constituent α that contains a high or mid central vowel"
(c) $^*\mathrm{Hd}_\alpha$/*ɨ,ə,i•u* "Incur a violation for every head of constituent α that contains a central or high peripheral vowel"

(d) $^*\mathrm{Hd}_\alpha/$*i,ə,i•u,e•o* "Incur a violation for every head of α that contains either a central or non-low peripheral vowel"

(e) $^*\mathrm{Hd}_\alpha/$*i,ə,i•u,e•o,a* "Incur a violation for every head of α that contains either a central or peripheral (i.e. any) vowel."

There are specific instantiations of the constraints in (4) for each level of the prosodic hierarchy. From the data given above, it is impossible to tell for Takia whether sonority refers to foot heads (i.e. all stressed syllables) or PrWd heads (i.e. just the main-stressed syllable). Either will work for Takia, so reference to foot heads will be arbitrarily assumed here as it makes no difference to the main points of the analysis. (Other types of head and non-head are discussed in Section 12.3.) So, $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i,ə,i•u* is violated whenever a stressed syllable (i.e. the head of a foot) contains a high central, mid central, or high peripheral vowel. For example, [(ˈpɨka)(ˌtəki)(ˌtipa)] violates it three times, as do [(ˈpika)(ˌtiki)(ˌtipa)] and [(ˈpəka)(ˌtəki)(ˌtəpa)].

The term 'head' is slightly imprecise as it has been used in a variety of different ways. For the cases discussed here, the 'head of α' is the nuclear vowel of α dominated by a series of prosodic heads up to α-level. See Zec's (8.5.1, 2000, 2003) theory of prosodic thresholds and de Lacy's (1999b, 2002a, 2006) Designated Terminal Element theory for more explicit approaches to prosodic reference.

Avoidance of stressed high vowels

The forms in (5) show the influence of the $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i,ə,i•u* constraint. Stress could fall on the default (i.e. rightmost) syllable, but doing so would result in a stressed high peripheral vowel when there is a more desirable non-high vowel elsewhere in the word. Instead, stress is attracted away from a fixed position on the final syllable to fall on the highest sonority syllable.

(5) *Avoidance of stressed high vowels in Takia*

(a) Avoidance of [ˈi]

[ˈabi]	'garden'	[iˈlodi]	'their insides'
[ŋiˈemi]	'your (pl.) legs/feet'		

(b) Avoidance of [ˈu]

[ˈnanun]	'child-3sg.'	[bugaˈgaru]	'twins'
[ˈsobul]	'feast, celebration'	[ˈbemfufu]	'index finger'

Tableau (6) illustrates with the word [ˈbemfufu]. Candidate (a) fares best in terms of the foot-form and location constraints, but in doing so fatally violates $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i,ə,i•u*. In contrast, candidate (b) avoids violations of $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i,ə,i•u* by stressing the initial mid vowel, and in doing so violates both ALIGN-R and IAMB. Even though Takia does not allow central vowels on the surface, the constraint $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i,ə,i•u* is used here because constraints are universal – i.e. there is no $^*\mathrm{Hd}_{\mathrm{Ft}}/$*i•u*.

(6) *Avoidance of stressed high vowels*

/bemfufu/	*Hd$_{Ft}$/i,ə,i•u	ALIGN-R(Ft,PrWd)	IAMB
(a) bem(fuˈfu)	*!		
☞ (b) (ˈbemfu)fu		*	*

Avoidance of stressed mid vowels

Similarly, the forms in (7) show that mid vowels are avoided when there is a higher sonority option. This can be formally expressed by using *Hd$_{Ft}$/*i,ə,i•u, e•o*, as in tableau (8).

(7) *Avoidance of stressed mid vowels in Takia*

[tiˈmanek]	'meeting'	[ŋiˈsaŋes]	'hawk'
[ˈŋasol]	'I run away'	[kaˈnaorig]	'earthquake'
[kaˈnagioi]	'name of peak on external rim of Karkar crater'		

(8) *Avoidance of stressed mid vowels*

/kanaorig/	*Hd$_{Ft}$/i,ə,i•u,e•o	*Hd$_{Ft}$/i,ə,i•u	ALIGN-R(Ft,PrWd)	IAMB
(a) kana(oˈrig)	*!	*		
(b) ka(naˈo)rig	*!		*	
(c) (ˈkana)orig			* *	*!
☞ (d) (kaˈna)orig			* *	

Candidates (a) and (b) fatally violate *Hd$_{Ft}$/*i,ə,i•u,e•o* by having a non-low vowel as a foot head. As candidate (d) has a stressed [a], it wins despite its foot being two syllables from the right edge. Candidate (c) also has a stressed [a], but violates the metrical constraints more than (c).[5]

Emergent edge attraction

Despite the fact that the *Hd$_{Ft}$-sonority constraints dominate, the metrical constraints are still active in the system. Their effect emerges whenever there is a 'tie' on constraint violation of the *Hd$_{Ft}$-sonority constraints. This happens most strikingly when there are only high vowels in a word, as illustrated in tableau (9). All the candidates equally violate the *Hd$_{Ft}$-sonority constraints, so ALIGN-R and IAMB are crucial in eliminating the competitors.

(9) *Emergent effect of metrical constraints*

/ifini/	*Hd$_{Ft}$/i,ə,i•u,e•o	*Hd$_{Ft}$/i,ə,i•u	ALIGN-R(Ft,PrWd)	IAMB
(a) (ˈifi)ni	*	*	*!	*
(b) (iˈfi)ni	*	*	*!	
(c) i(ˈfini)	*	*		*!
☞ (d) i(fiˈni)	*	*		

Do feet exist in Takia?

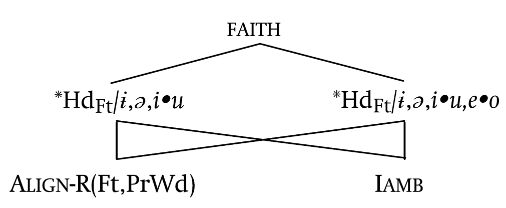
The preceding analysis has assumed that PrWds are parsed into feet. This assumption is based on the hypothesis that all languages employ all prosodic constituents in the Prosodic Hierarchy, including feet. The fact that foot form is blithely ignored in Takia's stress system does not mean that feet do not exist in the language. In fact, there is evidence that they are important. All of the content words cited by Ross (2002, 2003) are minimally disyllabic; none have the form [(C)V(C)]. As Kager (Ch.9) explains, such minimal word restrictions can be accounted for by requirements on the form of feet. Specifically, FtBin-σ "Feet are disyllabic" (based on McCarthy & Prince's 1986 FtBin) must outrank a relevant faithfulness constraint so that underlying /pa/ would surface as [pa<u>ta</u>] (through epenthesis) or Ø (through deletion).[6] In any case, the influence of foot structure is evident in many sonority- and tone-driven stress systems, and will be discussed in Section 12.3.

The final main-stress ranking

Some rankings cannot be determined from the available data. For example, there is no way to determine the ranking of *Hd$_{Ft}$/*i,ə,i•u* and *Hd$_{Ft}$/*i,ə,i•u,e•o* with respect to each other. Even more acutely, the ranking of *Hd$_{Ft}$/*i,ə,i•u,e•o,a* cannot be determined in regard to the constraints discussed above as every winning candidate violates this constraint in Takia. Similarly, the ranking of constraints such as *Hd$_{Ft}$/ɨ cannot be determined as Takia bans [ɨ] on the surface (by means of *Nuc/ɨ – Prince & Smolensky 2004). I add that the ranking of constraints in a stringency relation can be determined in some cases if there is another constraint C which dominates one constraint and is dominated by the other (see de Lacy 2006 Sec.5.3.2 for an example).

Takia's response to the sonority-head conditions is to deviate from the default metrical structure, and not delete the offending elements (/abi/ → ['ab]), epenthesize (/abi/ → [abi'<u>a</u>]), neutralize (/abi/ → [a'ba]), or metathesize (/abi/ → [i'ba]). Faithfulness constraints must therefore outrank the head-sonority constraints; these are discussed further in Section 12.6 but grouped under Faith here (10).

(10) *Takia's sonority-driven stress ranking*



Expressing universality

The constraints make it impossible to produce an 'anti-Takia' system where stress seeks out high vowels, then mid vowels, and only grudgingly falls on [a].

For such a language, there would have to be a freely rankable constraint that assigns a violation to [ˈa] but not to any less sonorous stressed vowel: i.e. $^{*}\mathrm{Hd_{Ft}}$/a. However, there is no such constraint in the set provided in (4).[7] Similarly, to have stress avoid mid vowels and favour high vowels, there would have to be a constraint $^{*}\mathrm{Hd_{Ft}}$/*e•o* (or $^{*}\mathrm{Hd_{Ft}}$/*a,e•o*). Again, there is no such constraint. In fact, no matter how the $^{*}\mathrm{Hd_{Ft}}$-sonority constraints are ranked, stressed low vowels will always be favoured over stressed mid- and high-peripheral vowels, and stressed mid-peripheral over high-peripheral vowels, and so on. This follows from the form of the constraints. Their effect can be seen visually in the quasi-tableau (11). Every stressed vowel incurs a proper subset of violations of all the less sonorous stressed vowels, so no matter how the constraints are ranked, the relative markedness of the vowels will remain the same. In this way, the constraint's form expresses the universal relations in the sonority hierarchy.

(11) *A stringency relation produces universal markedness implications*

	$^{*}\mathrm{Hd_{Ft}}$ /*ɨ*	$^{*}\mathrm{Hd_{Ft}}$ /*ɨ•ə*	$^{*}\mathrm{Hd_{Ft}}$/ /*ɨ•ə•i,u*	$^{*}\mathrm{Hd_{Ft}}$ /*ɨ•ə•i,u•e,o*	$^{*}\mathrm{Hd_{Ft}}$ /*ɨ•ə•i,u•e,o•ɛ,ɔ•a*
ˈɨ	*	*	*	*	*
ˈə		*	*	*	*
ˈi/ˈu			*	*	*
ˈe/ˈo				*	*
ˈa					*

12.2.2 Typology and fixed ranking

The theory of sonority-driven stress presented above expresses the sonority hierarchy through constraint form. An alternative is to employ a universally fixed ranking, and yet another is to rely less on constraints and more on representation. Both approaches will be discussed below.

Hierarchy through fixed ranking

Kenstowicz (1997/2004) proposes that the sonority-head constraints are in a universally invariant ranking, with the form in (12). The symbol '»»' denotes a 'fixed ranking'.

(12) *Universally fixed ranking*

$^{*}\mathrm{Hd_{Ft}}$/ɨ »» $^{*}\mathrm{Hd_{Ft}}$/ə »»$^{*}\mathrm{Hd_{Ft}}$/i,u »»$^{*}\mathrm{Hd_{Ft}}$/e,o »»$^{*}\mathrm{Hd_{Ft}}$/a

The Fixed Ranking approach can deal with Takia equally as well as the Stringency approach by the ranking || $^{*}\mathrm{Hd_{Ft}}$/i,u » $^{*}\mathrm{Hd_{Ft}}$/e,o » ALIGN-R(Ft,PrWd), IAMB ||. However, it makes different typological predictions from the stringency theory.

The differences relate to whether sonority categories can be ignored. The Stringent Markedness approach allows for categories to be collapsed (or 'conflated'). For example, a constraint such as *$\mathrm{Hd}_{\mathrm{Ft}}$/*ɨ,ə,i•u* assigns the same violations to both stressed central and high peripheral vowels, thereby allowing a situation where central and high peripheral vowels might be treated in the same way for stress purposes. In contrast, the Fixed Ranking approach prevents such conflation.

A relevant example is found in the Uralic language Nganasan (de Lacy 2004; data from Castrén 1854, Helimski 1998). The default position for stress is on the penult: e.g. [a'baʔa] 'older sister, aunt'. However, stress will avoid a penultimate central or high peripheral vowel whenever it can: e.g. ['aniʔə] 'large', ['baruʃi] 'devil', ['neɡyʃa] 'tease', ['ɟembiʔʃi] 'dressing', ['solətu] 'glass' (FtBin and Trochee block options such as *[neɡy('ʃa)], *[ne(ɡy'ʃa)]). Both theories can successfully model this pattern by having constraints against central and high peripheral vowels outrank Align-R(Ft, PrWd). In the Fixed Ranking theory, || *$\mathrm{Hd}_{\mathrm{Ft}}$/ɨ » *$\mathrm{Hd}_{\mathrm{Ft}}$/ə » *$\mathrm{Hd}_{\mathrm{Ft}}$/i,u » Align-R (Ft,PrWd) || would account for the avoidance, as in tableau (13).

(13) *Nganasan with Fixed Ranking produces sonority-driven stress*

/baruʃi/	*$\mathrm{Hd}_{\mathrm{Ft}}$/ɨ	*$\mathrm{Hd}_{\mathrm{Ft}}$/ə	*$\mathrm{Hd}_{\mathrm{Ft}}$/i,u	Align-R(Ft,PrWd)
(a) ba('ruʃi)			*!	
☞ (b) ('baru)ʃi				*

Tableau (13) helps see a strong prediction of the Fixed Ranking theory: it predicts that stress should avoid a penultimate schwa for high vowels. A word like *cintəɟi* 'stoke' should be stressed on the antepenult because [cin('təɟi)] would fatally violate *$\mathrm{Hd}_{\mathrm{Ft}}$/ə. However, Nganasan does not distinguish between central and high peripheral vowels for stress purposes; stress does not retract off a central vowel onto a high peripheral vowel: e.g. [cin('təɟi)] 'stoke', *[('cintə)ɟi]; [kun('sɨnɨ)] 'inside', *[('kunsɨ)nɨ]. The problem is illustrated in tableau (14). The symbol 💣 indicates that the wrong winner is chosen.

(14) *Nganasan with Fixed Ranking prevents conflation*

/cintəɟi/	*$\mathrm{Hd}_{\mathrm{Ft}}$/ɨ	*$\mathrm{Hd}_{\mathrm{Ft}}$/ə	*$\mathrm{Hd}_{\mathrm{Ft}}$/i,u	Align-R(Ft,PrWd)
(a) cin('təɟi)		*!		
💣 (b) ('cintə)ɟi			*	*

In contrast, the Stringent Markedness theory allows for the collapse of category distinctions. To get stress to favour mid peripheral and low vowels over high peripheral and central vowels, *$\mathrm{Hd}_{\mathrm{Ft}}$/*ɨ,ə,i•u* must outrank Align-R (Ft, PrWd). However, no other head-sonority constraint has to, crucially including *$\mathrm{Hd}_{\mathrm{Ft}}$/*ɨ* and *$\mathrm{Hd}_{\mathrm{Ft}}$/*ɨ,ə*. The effect is that stress treats central and high peripheral vowels equally, as shown in tableau (15). Because *Hd$_{Ft}$/*ɨ* and *Hd$_{Ft}$/*ɨ,ə* are ranked below ALIGN-R(Ft,PrWd), they have no effect on the outcome.

(15) *Nganasan with Stringent constraints*

	/cintəɟi/	*Hd$_{Ft}$/*ɨ,ə,i,•u*	ALIGN-R(Ft,PrWd)	*Hd$_{Ft}$/ɨ,ə	*Hd$_{Ft}$/ɨ
	(a) (ˈcintə)ɟi	*	*!		
☞	(b) cin(ˈtəɟi)	*		*	

In short, the Stringent theory is empirically more adequate than the Fixed Ranking theory – Fixed Ranking prevents attested cases where distinctions between sonority categories are ignored for stress purposes.

Typology

The table in (16) summarizes the typological predictions of the Stringency Theory, including cases with conflation. Almost every possible contiguous conflation in stress-sonority interaction is attested. Categories are marked as conflated if they are grouped inside the same oval. For example, the mid and low vowels are conflated in Pichis Asheninca, but the central and high vowels are not.

For ease of presentation the table uses ‘ɨ/ə’ to stand for any central vowel (e.g. Pichis Asheninca has [ɨ], not schwa); in any case, it is rare to find a language with a contrast between /ə/ and /ɨ/ (Nganasan is one of the few). Similarly ‘e o’ stands for all mid vowels, including [e o ɛ ɔ] even though [e o] are demonstrably less sonorous than [ɛ ɔ] (see de Lacy 2006:Ch.7).

(16) *Head-sonority conflation typology*

Categories	*Languages*
ɨ/ə i/u e/o a	Gujarati (de Lacy 2002a:Ch.3, 2006: Sec.5.3.2)
ɨ/ə i/u e/o a	Pichis Asheninca (J.Payne 1990)
ɨ/ə i/u e/o a	Yil (Martens & Tuominen 1977)
ɨ/ə i/u e/o a	–
ɨ/ə i/u e/o a	Nganasan (de Lacy 2004)
ɨ/ə i/u e/o a	Kara (Schlie & Schlie 1993, de Lacy 1997)
ɨ/ə i/u e/o a	*All vowels are treated the same*

The different systems are generated by different sets of active constraints. The Gujarati system, for example, is due to both *Hd$_{Ft}$/*ɨ,ə,i•u,e•o* and *Hd$_{Ft}$/*ɨ,ə* being active, while *Hd$_{Ft}$/ *ɨ,ə,i•u* is not (to allow conflation of high and mid vowels) (see de Lacy 2006 Sec.5.3.2). The table also shows that almost every imaginable conflation of vowel sonority is attested: any set of contiguous categories can be conflated.

There are two systems missing from the table. One is a language that distinguishes all sonority levels: i.e. ə vs. i/u vs. e/o vs. a. Kobon is reported to have such distinctions (Kenstowicz 1997/2004), but Davies' (1981) data only provide evidence for the distinctions | a ⟩ o ⟩ i, ə ⟩ ɨ | – i.e. high vowels and schwa could be conflated. Given the existence of languages like Takia and Nanti (Crowhurst & Michael 2005) which distinguish every sonority level they have (i.e. *i,u* vs. *e,o* vs. *a*) it is likely that this gap is due to the limited range of data currently available rather than signifying a theoretical issue.

Similarly, I have not found a system that definitely conflates [ˈə] and [ˈi ˈu] but distinguishes mid from low vowels. In such a language, stress would first seek out a low vowel and otherwise a mid vowel; if there were only high and central vowels, stress would fall on the default position. Given that there are languages in which stress favors low vowels over mid vowels (e.g. Gujarati) and languages in which high peripheral vowels and schwa are conflated (e.g. Nganasan), I assume that this gap is accidental.

There are a number of languages that have stress systems that are insensitive to sonority, even though they have very low sonority vowels. My own dialect of New Zealand English is one: schwa (which corresponds to [ɪ] in many other dialects) can be stressed and more sonorous vowels do not attract the stress away from it: e.g. [dʒuˈdʒətsu] 'jujitsu', *[ˈdʒudʒətsu], /həstɔɹi/ 'history' → [ˈhəstəɹi]/[ˈhəstʃɹ̥i], *[həˈstɔri]. Other languages include Iaai (Lynch 2002) which has the vowels [a ɛ ɔ e o i u ə], with consistent word-initial stress and schwa permitted word-initially.

Theoretically significant gaps are those in which stress seeks out lower sonority vowels and disregards higher sonority ones. Such systems are unattested, as predicted by the constraint-based theories.

There is one other systematic and theoretically significant gap: no language conflates non-contiguous categories. An example would be a language which conflates low and high vowels, but not mid vowels: stress would fall on the leftmost [a], [i], or [u], and skip over intervening mid vowels [e] and [o]. The stringent constraints predict that such a language cannot exist. It would require a constraint that favored stressed high vowels over stressed mid vowels (e.g. *Hd_{Ft}/mid vowels) and there is no such constraint in the theory.

Sonority, or something else?

After Kenstowicz (1997/2004), the discussion above has assumed that Takia and systems like it are sensitive to sonority rather than some other hierarchy. In contrast, Crowhurst & Michael (2005:70) propose that such stress systems are instead sensitive to two separate hierarchies: one on vowel height (HEIGHTPK: | high ⟩ mid ⟩ low |), and one on vowel peripherality (PERIPHPK: | central ⟩ peripheral |) (also see Smith 2002 Sec.23.2.2-fn.48).

This proposal essentially splits the sonority hierarchy along its two major dimensions (at least for vowels).

There are two problems with this view. One is that it incorrectly prevents central and peripheral vowels from conflating. To explain why, it is first necessary to point out that the constraints from PeriphPk (i.e. $^{*}Hd_{Ft}$/high »» $^{*}Hd_{Ft}$/mid »» $^{*}Hd_{Ft}$/low) must be universally outranked by the constraints from HeightPk (i.e. $^{*}Hd_{Ft}$/central »» $^{*}Hd_{Ft}$/peripheral). If the opposite ranking was permitted, it would generate a language where foot heads avoid high peripheral vowels [i u] for the mid central vowel schwa: i.e. $^{*}Hd_{Ft}$/high » $^{*}Hd_{Ft}$/central would favor ['pəki] over [pə'ki] even in a system with default rightmost stress. However, there is no such language. This result holds regardless of whether fixed ranking or stringency is used. However, if $^{*}Hd_{Ft}$/central universally outranks $^{*}Hd_{Ft}$/high, it is impossible to conflate schwa and high vowels, incorrectly predicting that Nganasan is impossible for the same reason as illustrated in tableau (14). In short, to allow for conflation of central and peripheral vowels, it is crucial for them to be on the same hierarchy, therefore ruling out approaches that appeal to vowel height and peripherality as separate hierarchies.

The other problem with approaches that seek to eschew sonority in favor of sub-hierarchies of features is that stress is never sensitive to features apart from sonority and tone. There is no system in which, for example, stress falls on the leftmost round vowel, or nasal vowel, and so on (de Lacy 2002a). Therefore, no stress system could refer directly to height *features* like [±high] and [±low] (and [±round], and so on). In contrast, sonority is arguably not a subsegmental feature – it behaves like manner features, which McCarthy (1988) proposes inhabit the root node.

12.2.3 Representational approaches

The two approaches discussed so far are both based on the assumption that markedness effects should be expressed through constraint form or ranking; this idea began with Prince & Smolensky (2004[1993]) and Smolensky (1993). An entirely different class of theory employs representational devices. Both Hayes' (1995:Ch.7) 'prominence grid' proposal and the approach of representing distinctions through moraic or featural content will be discussed here.

Prominence grids

Hayes (1995:Ch.7), building on Halle & Vergnaud (1987), Davis (1989b) and Everett & Everett (1984), proposes a device called a 'prominence grid'.[8] A prominence grid is akin to a metrical grid (see Kager 9.2.1), but the grid-marks are assigned to syllables on the basis of certain properties. For example, Takia syllables with [a] would be assigned three grid-marks, syllables with mid vowels would get two, and syllables with high vowels just one. General rules or constraints require that the head syllable have the

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highest prominence grid-mark (in OT the prominence grid is accessed through the constraint PkProm – Prince & Smolensky 2004).

While prominence grids are empirically adequate in accounting for sonority-driven stress – and every other type of stress – they are much too powerful when compared with approaches such as Kenstowicz' (1997/2004). Prominence grids are unique devices: as Hayes (1995:274) observes, they are not like true metrical grids as they do not avoid clash or lapse (Kager 9.2.1). In contrast, the constraint formation mechanism that accounts for sonority-driven stress discussed above is not unique to foot–sonority relations; it also applies to tone (12.4) and can motivate deletion, epenthesis, metathesis, and neutralization (12.6). While prominence grids are transitory devices, and are only relevant to one rule or one constraint (i.e. PkProm), Kenstowicz' proposal refers to an inherent property of segments – sonority – and one that can be accessed by any relevant constraint (or rule). The proposal also made a direct formal relation between sonority-driven stress and syllable construction, a relation that prominence grids obscure.

On the empirical side, Hayes' prominence grid formalism predicts that sonority and tone are irrelevant to foot construction (1995:272). Evidence against this prediction is found in systems where secondary stress (i.e. foot location) is influenced by sonority (see Section 12.3, McGarrity 2003, Crowhurst & Michael 2005). In short, the constraint-based approach avoids employing a transitory rule/constraint-specific device that unnecessarily abstracts away from properties such as sonority and tone.

Moras and featurelessness

An entirely different approach is to rely on the representation of individual segments to account for their behavior with stress. For example, a number of authors have proposed that schwa lacks subsegmental features, or a mora, or both (for recent discussion, see e.g. Oostendorp 1995, Crosswhite 2004). This idea is part of a broader approach to markedness that attempts to derive markedness relations from aspects of representation (e.g. Paradis & Prunet 1991b, Rice 1996, Morén 2003, and many others; cf. de Lacy 2006 Sec.8.4 and references cited therein for critical appraisal).

The 'moraic' approach postulates that all syllable distinctions in stress are due to moraic content. In Gujarati, for example, stress seeks out [a] over [ɛ ɔ e o i u], and avoids [ə] whenever possible. In a moraic approach, Gujarati [ə] could have no moras, [a] two, and the other vowels one; preference for stressed syllables with greater moraic content would produce the observed stress system. In such an approach conflation is a side-effect of mora assignment; it is the fact that high and mid vowels have the same moraic content that results in their conflation.

In effect, the moraic approach to sonority-driven stress outlined above converts moras into little more than a language-specific diacritic device that is almost synonymous with sonority. However, there is a difference between it and the sonority approach. Because moras represent duration, they make undesirable predictions for phonetic realization. In Gujarati, low vowels should be appreciably longer than high and mid vowels, and all should be longer than schwa. This is not so: there is no significant difference between [a]'s duration and the other vowels' in Gujarati (de Lacy 2002a, 2006). The same point can be made for other languages. For example, Takia's high vowels would have to have one mora, mid vowels two, and [a] three; however, Ross does not report any significant length difference between them. Nganasan distinguishes two groups of vowels for stress: [ɨ ə i y u] and [a e o]. The former group cannot have fewer moras than the latter because there is no significant durational difference between the two sets (de Lacy 2004 Sec.2.6.3). Finally, as Nina Topintzi (p.c.) observes, moraic approaches face a significant challenge when a language's stress placement relies on both sonority and a syllable's moraic content (e.g. Nanti – Crowhurst & Michael 2005).

Representational theories also make strong predictions about other processes in the same language. Proposing that low vowels have more moras than other vowels predicts that they can – and perhaps must – be treated differently for other mora-referring processes. This prediction is criticized at length by Gordon (1999).

Another popular representational theory relates specifically to the opposition between schwa and peripheral vowels, and relies on the idea that schwa lacks phonological features (e.g. Oostendorp 1995 and references cited therein). With additional theoretical devices, this fact makes schwas 'weak', and consequently unable to bear stress. This theory is one of a class that considers schwa to be fundamentally phonologically different from all other vowels. In contrast, the approach to stress proposed here denies that schwa is significantly different from other vowels in phonological terms – the only difference is that schwa is lower on the sonority hierarchy than (most) other vowels.

A problem with relating lack of features to stress avoidance arises in languages in which schwa is conflated with other vowels. In Nganasan, [ɨ], [ə], and [i y u] repel stress equally – i.e. they are conflated for stress purposes. If lack of features is the reason that schwa repels stress, then all of [ɨ ə i y u] must be featureless. However, if all these vowels are featureless, then they should be phonologically indistinguishable. At the very least, it is clear that featurelessness is not sufficient on its own to account for stress repulsion.

In the constraint-based approach, there is no need to appeal to lack of features or any other representational devices. Schwa is not fundamentally different from other vowels in terms of its representation. It is simply low on the sonority hierarchy; its behaviour in phonological processes follows from its sonority level, not from its lack of features. In short, attempts to deal with sonority-driven stress by appealing to representational differences among vowels lead to unsupported predictions regarding duration, mora-sensitive phonological processes, or difficulties in accounting for vowel contrasts. For further critiques of representational theories of stress, see Gordon (1999), and de Lacy (2002a Sec.3.3.4, 2004 Sec.2.6.3). For a general critique of representational theories of markedness, see de Lacy (2006 Sec.8.4) and the references cited therein (cf. Rice 1996, to appear).

12.3 Non-heads and other levels

Prince & Smolensky's (2004) proposal about sonority and syllable structure not only draws a relation between syllable heads (i.e. nuclei) and sonority, but also between non-heads (i.e. margins) and sonority (see Zec 8.5.2). If sonority-driven stress is analogous to syllable form, it is therefore expected that there could be constraints on non-heads of feet. In addition, the reverse sonority relation should apply: non-heads should prefer low sonority elements, with the resulting constraints as in (17), adapting a proposal by Kenstowicz (1997/2004), and explored further in de Lacy (2002a,b, 2004).

(17)

(a) *non-Hd$_{\alpha}$/*a*	"Incur a violation for every non-head of constituent α that contains a low vowel"
(b) *non-Hd$_{\alpha}$/*a,e•o*	"Incur a violation for every non-head of α that contains either a low or mid peripheral vowel"
(c) *Hd$_{\alpha}$/*a,e•o,i•u*	"Incur a violation for every non-head of α that contains either a high, mid, or low peripheral vowel."
	...and so on.[9]

The effect of such constraints can be seen in Kiriwina (de Lacy 2004 Sec.4; for other cases, see Kenstowicz 1997/2004, de Lacy 2002a:Ch.4). As shown in (18a), a quantity-sensitive trochaic foot is built at or as near to the right edge of the PrWd as foot binarity will allow (CVV and CVC are heavy) (see Kager 9.2.3.2). However, the foot will appear away from the right edge if doing so will allow it to have a lower sonority non-head (i.e. a high vowel), in (18b).

(18) *Kiriwina sonority-driven stress (Senft 1986, Lawton 1993)*

(a) Right-aligned trochee

(i) Final heavy syllable ((C)VC, (C)VV)

[i.ki('um)]	'he did secretly'	[tau('au)]	'hey, men!'

(ii) Penultimate heavy syllable

[('peu)la]	'strong'	[am('bai)sa]	'where?'

(iii) Penultimate and final light ((C)V) syllables

ka('wala)	'canoe pole'	bo('nara)	'shelf (in house)'
igibu('lu.i)	'he is angry at'	[i.koi.('su.vi)]	'he puts in'

(b) Except when foot retraction would result in a low-sonority non-head

[('migi)la]	'the face'	[('kuli)a]	'cooking pot'
[('megu)va]	'white magic'	[('lugu)ta]	'yam type'
[('lami)la]	'outrigger log'	[katusa('wasi)la]	'clear throat'
[la('siku)la]	'pull canoe'		

It is clear that Kiriwina is not concerned with the sonority of its foot *head*. In [('migi)la] the foot is not aligned with the right edge even though its competitor *[mi('gila)] has the *same quality* stressed vowel. Instead, what matters is the sonority of the non-head vowel of the foot: in *[mi('gila)] the foot has a very high sonority non-head vowel [a], whereas in [('migi)la] it has a low sonority one – i.e. [i].

This pattern is generated by ranking *non-Hd$_{Ft}$/*a,e•o* over the constraints that require right-alignment: i.e. ALIGN-R(Ft,PrWd) (19):

(19) *Kiriwina: Non-head sonority*

/migila/	*non-Hd$_{Ft}$/*a,e•o*	ALIGN-R(Ft,PrWd)
(a) mi('gila)	*!	
☞ (b) ('migi)la		*

Interaction with metrical structure

It is interesting to note that Kiriwina is far more respectful of metrical restrictions than Takia. In its desire to have a high sonority stressed vowel, Takia will tolerate trochees instead of iambs. In contrast, Kiriwina will only tolerate trochees: i.e. *[mi(gi'la)] is banned, and so is *[vi('la)] (cf. [vi#('vila)] 'woman'); in constraint terms, TROCHEE outranks *non-Hd$_{Ft}$/*a,e•o* in Kiriwina. Kiriwina will not tolerate degenerate feet, either: ['waga], *[wa('ga)] 'canoe'; *[mi('gi)la]. The contrast can be generalized to the rankings in (20).

(20) *Interaction of sonority conditions with metrical conditions*

"π/son" regulates the interaction of prosodic structure with sonority
(e.g. *Hd$_{Ft}$/ɨ)
"π-align" regulates the position of prosodic structure (e.g. ALIGN-R(Ft,PrWd))
"π-shape" regulates the shape and size of prosodic structure (e.g. FTBIN)

(a) || π/son » π-align, π-shape ||
(e.g. Takia; Nanti – Crowhurst & Michael 2005)
Sonority conditions take precedence over both position and shape

(b) || π-shape » π/son » π-align ||
(e.g. Kiriwina; Gujarati – de Lacy 2006)
Sonority conditions take precedence over position, but not shape

(c) || π-align » π/son » π-shape || (e.g. Harar Oromo – de Lacy 2002a:Ch.4)
Sonority conditions can force a change in shape, but only within a 'window'

(d) || π-align, π-shape » π/son || (e.g. Iaai)
Sonority has no effect on stress placement

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Further details of the analysis of Kiriwina are given in de Lacy (2004 Sec.4). For a particular striking example of a system in which sonority interacts with metrical conditions, see Crowhurst & Michael (2005).

12.4 Tone

The same constraint mechanism that was used with sonority also applies to the tonal hierarchy | High ⟩ Mid ⟩ Low |. The constraints proposed in de Lacy (2002b) are expressed with stringent form in (21). Precursors to these constraints include Goldsmith's (1987) 'Tone–accent attraction condition', which favors accented syllables with specified tone over accented toneless syllables, and Jiang-King's (1996:99) proposal that there is a tonal hierarchy | +Upper ⟩ −Raised | (see Yip 10.2.1) (also see Hayes 1995 Sec.7.1.3); for further discussion see Yip (2001a; 2002 Sec.3.9; 10.3.2).

(21) *Tone-head, and -non-head constraints (after de Lacy 2002b)*
(a) *Hd$_{\alpha}$/*L*, *Hd$_{\alpha}$/*L•M*, *Hd$_{\alpha}$/*L•M•H*
(b) *non-Hd$_{\alpha}$/*H*, *non-Hd$_{\alpha}$/*H•M*, *non-Hd$_{\alpha}$/*H•M•L*

The effect of both sets of constraints can be seen in Ayutla Mixtec. The foot is attracted to the left edge of a word, as seen in (22a). However, the foot will appear elsewhere if the 'perfect toned foot' can be produced: i.e. where the head has a high tone and the non-head has a low tone.

(22) *Ayutla Mixtec tone-driven stress (data from Pankratz & Pike 1967)*
(a) Default = leftmost trochaic foot

('HH)H	[('ʃíní)rá]	'he understands'
('LL)L	[('ʃàtù)ì]	'my trousers'
('MM)M	[('ʃĩ̄ɲū)rā]	'his pineapple'

(b) Deviate from leftmost position in order to:
(i) Create the tonally perfect foot ('HL)

H('HL)	[lú('lúrà)]	'he is small'
LM('HL)	[lùlū('úrà)]	'he is not small'

(ii) Else create a degenerate foot with a H-toned head

ML('H)	[kūnù('rá)]	'his tobacco'

(iii) Else create the next best foot ('ML)

L('ML)	[tì('kātʃìʔ)]	'whirlwind'
M('ML)	[lā('ʃārà)]	'his orange'

Attraction of the foot head to a high-toned syllable can be dealt with by having *Hd$_{Ft}$/*L•M* outrank ALIGN-L(Ft,PrWd) and FTBIN, as in tableau (23). To make candidates easier to read, forms like /kūnùrá/ are schematized as candidates as [ML('H)] and so on.

(23) *Seeking out a H-toned head, regardless of the metrical cost*

	/kūnùr̀a/	*$\mathrm{Hd_{Ft}}$/*L•M*	FtBin	Align-L(Ft,PrWd)
	(a) (ˈML)H	*!		
	(b) M(ˈLH)	*!		*
☞	(c) ML(ˈH)		*	* *

*$\mathrm{Hd_{Ft}}$/*L* is also crucial in favoring mid- over low-toned heads (24):

(24) *Seeking out a mid-toned head*

	/ʃàkùūrìʔ/	*$\mathrm{Hd_{Ft}}$/*L•M*	*$\mathrm{Hd_{Ft}}$/L	Align-L(Ft,PrWd)
	(a) (ˈLL)ML	*	*!	
☞	(b) LL(ˈML)	*		* *

The importance of non-heads is seen in forms like [lú(ˈlúrà)] 'he is small' (i.e. [H(ˈHL)]). The competitor *[(ˈlúlú)rà] ([(ˈHH)L)]) also has a high-toned foot head; the only difference is in the foot non-head's tone. Having *non-$\mathrm{Hd_{Ft}}$/H•M outrank Align-L(Ft,PrWd) is responsible here (25):

(25) *Seeking out a low-toned non-head*

	/lúlúrà/	*non-$\mathrm{Hd_{Ft}}$/ *H•M*	*$\mathrm{Hd_{Ft}}$/ *L•M*	*$\mathrm{Hd_{Ft}}$/ *L*	FtBin	Align-L(Ft,PrWd)
	(a) (ˈHH)L	*!				
	(b) (ˈH)HL				*!	
☞	(c) H(ˈHL)					*

*non-$\mathrm{Hd_{Ft}}$/*H•M* is needed (as opposed to *non-$\mathrm{Hd_{Ft}}$/*H*) to account for [lā(ˈʃārà)] – i.e. [M(ˈML)] (not *[(ˈMM)L]).

The tableau also shows that there is a crucial ranking between FtBin and Align-L. Without this ranking, feet would be degenerate in order to be better-toned.

Align-L(Ft,PrWd) is especially crucial in two contexts. One is where all syllables have the same tone, as in [(ˈʃíní)rá] (i.e. not *[ʃí(ˈnírá)], *[ʃíní(ˈrá)]). The other is when there are two HL or ML sequences in the same word: e.g. /ʃáàʃî/ 'is not eating' → [(ˈʃá.à)ʃí.ì], *[ʃá.à(ˈʃí.ì)].

In summary, the tonal hierarchy acts in a similar fashion to the sonority hierarchy. Tone-driven stress systems are reported in languages as genetically diverse as Chickasaw (Muskogean – Gordon 2003: Sec.4.3), Golin (East New Guinea Highlands – Bunn & Bunn 1970), Serbo-Croatian (Slavic – Inkelas & Zec 1988, Zec 1999), Tibetan (Sino-Tibetan – Meredith 1990), and Vedic Sanskrit (Indo-Aryan – Kiparsky & Halle 1977).

However, there is some disagreement over the form of tone-(non)head constraints. For example, Yip (2001a) argues that they must be formulated positively (cf. de Lacy 2002a: Sec.3.5.1.3).

Yip also emphasizes that positional faithfulness constraints for tone are needed in addition to the Head-tone constraints; see Yip (10.3.2) and Yip (2002) for discussion. There is no problem with having both positional markedness and positional faithfulness constraints. Both types seem necessary for many phenomena.

Tone and sonority?

The only interaction not discussed between tone, sonority, and prosody is between tone and sonority. In some languages, tone can only appear on sonorant coda consonants, but this type of restriction is often seen as an indirect relation between sonority and tone. In these cases, sonorants are assumed to be moraic while obstruents are not, and only moras can bear tone (see Gordon 2001 for recent discussion and references). I know of no other evidence that requires a direct relationship between sonority and tone. For example, there is no language in which low vowels must carry low tone while high vowels must be high-toned (this sort of restriction would make phonetic sense as there seems to be a correlation between low sonority and lower tone (e.g. for Thai, see Abramson 1962)). In constraint terms, there must be no constraint with the general form **son/tone*, where *son* is a sonority level (e.g. *{*a,e•o*}/*Low*, etc.).

12.5 Other prosodic levels

The theoretical proposals outlined above are not limited to feet. Some proposals allow sonority (and tone) to combine with heads and non-heads of *any* prosodic category (de Lacy 2002a, Zec 2003). Evidence for this view is presented here.

Below the foot are the syllable and the mora. The head of the syllable is its nucleus (i.e. the segment dominated by the head mora), and the preference for high sonority elements in nuclei is well documented (Prince & Smolensky 2004, Zec 8.5.1). Similarly, the 'non-head' of the syllable (i.e. its margins) favors low sonority segments; this preference is typically evident in syllabification, but can also exert itself in neutralization and even foot placement (de Lacy 2001, Smith 2002, Topintzi 2006).

The same is true for tone: as discussed in section 9.4, heads favor higher tone, and non-head moras favor lower tone. This is shown at the moraic level in the northern Min language Fuqing (Jiang-King 1996 Sec.3.3.2): only H and M tone can appear on head moras, and only L tone can appear on non-heads (i.e. monomoraic syllables can only have H or M tone, and bimoraic syllables can only have HL or ML contours).

McGarrity (2003) shows the need for sonority constraints that refer to the foot level. Most languages with sonority-driven stress have no reported secondary stress, so it is often not clear whether the motivating constraints refer to the head of the foot or PrWd. However, secondary stress avoids the least sonorous vowel [ɨ] in Yimas: [(ˈtɨŋkɨm)pɨ(ˌɲawa)] 'wild fowl', *[(ˈtɨɲkɨm)(ˌpɨɲa)wa]; cf. [(ˈmaman)(ˌtakar)man] 'land crab', *[(ˈmaman)ta(ˌkarman)]; there is clearly need for *Hd$_{Ft}$/*ɨ* here as opposed to *Hd$_{PrWd}$/*ɨ*. Crowhurst & Michael (2005) show the same for Nanti: sonority conditions can result in trochees instead of iambs even for non-head feet: e.g. [(ˌnabi) (gʒiˈta)ksero] 'it crushed it', *[(ˌnaˌbi)(gʒiˈta)ksero] (cf. [(iˌpi)(riˌni)te] 'he sits'). In addition, for Kiriwina it is crucial that non-heads of *feet* are sensitive to sonority: stress in [(ˈmigi)la] does not fall at the right edge because the unstressed vowel in the *foot* (i.e. not unfooted unstressed vowels) ends up with a less sonorous segment. McGarrity's general point is that in terms of sonority, secondary and primary stress are independent. A ranking such as || $^*\mathrm{Hd}_{\mathrm{Ft}}/x$ » ALIGN || will affect all stressed syllables, but || ALIGN-R-$\mathrm{Hd}_{\mathrm{PrWd}}$ » $^*\mathrm{Hd}_{\mathrm{Ft}}/x$ » ALIGN-R-Ft || will only affect secondary stressed syllables, while || $^*\mathrm{Hd}_{\mathrm{PrWd}}/x$ » ALIGN-R-Ft » $^*\mathrm{Hd}_{\mathrm{Ft}}/x$ || will only affect primary stressed syllables; all these types are attested. McGarrity (2003 Sec.4.2) also identifies Chamorro as having sonority-driven neutralization in secondary stressed syllables; this case is discussed in Section 12.6.

Immediately above the foot is the Prosodic Word. The head of the Prosodic Word is its main-stressed syllable (i.e. the segment dominated by the head mora of the head syllable of the head foot). Some languages place sonority and tone restrictions specifically on the head of the PrWd rather than the head of the foot. McGarrity (2003) identifies Axininca Campa as this type for sonority-driven stress (Payne 1990). Masset Haida provides an example for tone (Enrico 1991). As shown in (26), every syllable has either high or low tone, and iambic feet are arrayed from left to right; every syllable is parsed into a foot. As a visual aid, main-stressed syllables are given in bold. Main stress is attracted to the rightmost vowel with high tone. However, secondary stress makes no tone distinction, falling freely on low-toned vowels even when high-toned ones are available. Form (26d) is of special interest. While main stress falls on the rightmost high-toned syllable (i.e. [gwáːŋ], not [áː]), secondary stress falls on the low-toned [dà], ignoring the high-toned [áː]: i.e. *[(ɠùˌdàŋ)(ˌá-dà) - (t'sà-ˈgwáːŋ) - (ˌgàn)]. In other words, the position of the head of the PrWd is influenced by tone, but foot heads are not.

(26) *Masset Haida tone-driven primary stress and tone-insensitive secondary stress*

(a) [(ˌɠùː)(dàˈ**ŋáː**)-(dà-ˌt'sà)-(7wà-ˌgàn)] 'spy.on-causative-into-pl-past'
(b) [(kìlˌxàl)(dà:nh**láŋ**)-(ˌ.ìd)-(7wà-ˌgàn)] 'caus.-potential.be.slave-inceptive-pl-past'
(c) [(ˌɠàd)(làˌdàn)(jàn-ˈ**dáːl**)-(ˌgàŋ)] 'jump.up,iter.-along-pr'
(d) [(ɠùːˌdàŋ)(áː-ˌdà)-(t'sà-ˈ**gwáːŋ**)-(ˌgàn)] 'spy.on-causative-into-around-past'

In de Lacy (2002a, 2004) I argued that 'PrWd non-heads', when restricted by constraints on foot heads, can be used to refer to the informal notion of 'unstressed syllable'; the influence of sonority on unstressed syllables is discussed in Section 12.6.

The same type of influences are seen above the PrWd, though they are clearer for tone than sonority. For example, the head of a Phonological Phrase in Digo attracts high tone (Kisseberth 1984, Goldsmith 1988:85). This is a case of stress-dependent tone, with the constraint $^*\mathrm{Head}_{\mathrm{PPh}}/\mathrm{L}$ playing a decisive role. For Korean, Kim (1997) argues that every Major Phrase must contain at least one high tone and that no other high tones are permitted.

The constraints *Head$_{MajorP}$/L and *non-Head$_{MajorP}$/H must therefore outrank tone-faithfulness to achieve this result.

At the highest level, Yip (10.3.2) proposes the constraint *FOCUS/L, which bans a low tone on a focused head. Truckenbrodt (1995) argues that the focused syllable is the head of the Utterance Phrase (or some other high prosodic constituent), so the tonal preferences can be seen even at the highest prosodic level.

So, the same sonority and tone attractions are seen at every level in the prosodic hierarchy: heads of moras, syllable, feet, PrWd, Prosodic Phrases, and Utterance Phrases attract and are attracted by higher tone and high sonority segments, while non-heads of all these categories favor lower tone and lower sonority.

12.6 Faithfulness responses

In Optimality Theory, no constraint is phenomenon-specific (see 1.2.2). Constraints with the form *π/*p* (π is a prosodic category, *p* is a property like sonority or tone) have many possible resolutions. The previous sections have focused on just one: i.e. moving π, through the general ranking || *π/*son*, FAITH » π-{align,shape} ||. This section focuses on resolutions that involve *p* – through || *π/*son*, π-{align,shape} » FAITH || which can cause deletion, epenthesis, neutralization, metathesis and coalescence. In a sense, such resolutions are 'stress-driven sonority/tone': they are cases where prosodic structure is kept constant and sonority/tone changes.

12.6.1 Neutralization

The most common response to conditions on heads and sonority is probably neutralization. The most extensive recent work on this topic in OT is Crosswhite (1998 et seq.), who proposes that (non-)head-sonority relations are responsible for a great deal of vowel reduction. In foot heads, vowels can become more sonorous, while in foot non-heads and unstressed syllables they typically become less sonorous. For example, in Chamorro (27) high vowels become mid in stressed syllables:

(27) *Chamorro sonorization in stressed syllables (Chung 1983, Crosswhite 1998)*

/laːpis/	[ˈlaːpi̠s]	'pencil'	[laˈpe̠ssu]	'my pencil'
/hugandu/	[huˈgandu̠]	'play'	[ˌhuganˈdo̠ɲa]	'his playing'
/lægu?/	[maˈlæːgu̠ʔ]	'wanting'	[ˌmalæˈgo̠ʔmu]	'your wanting'

Sonorization is obligatory in main-stressed syllables and optional in secondary stressed syllables: e.g. [ti̠nˈtaguʔ] 'messenger' c.f. [ˌte̠ntaˈgoʔta]~[ˌti̠ntaˈgoʔta] 'our (incl.) messenger'.

Adapting Crosswhite's (1998) analysis, sonorization in Chamorro is caused when *Hd$_{Ft}$/ə,*i*•*u* outranks IDENT[high], a constraint that preserves underlying [high] values. It is crucial that metrical constraints (like TROCHEE and ALIGN-R(Ft,PrWd)) outrank IDENT[high] (also see McGarrity 2003) otherwise the system would have sonority-driven stress. All other relevant faithfulness constraints like those against deletion, epenthesis, metathesis, and so on must also outrank IDENT[high] (28).

(28) *Chamorro vowel sonorization in stressed syllables*

/lapissu/	*Hd_{Ft}/ə,*i*•*u*	ALIGN-R(Ft,PrWd)	IDENT[high]
(a) la(ˈpissu)	*!		
(b) (ˈlapis)su		*!	
☞ (c) la(ˈpessu)			*

The fact that main-stressed high vowels always become more sonorous can be accounted for by having *Hd_{PrWd}/ə,*i*•*u* outrank IDENT[high] in all registers; the optionality of sonorization for secondary stress can be explained by allowing *Hd_{Ft}/ə,*i*•*u* to vary in its ranking with IDENT[high] (see Anttila Ch.22).

The most common sonority-related neutralization involves vowels in foot non-heads or unstressed syllables becoming less sonorous. Often this involves all such vowels becoming [ə] or [ɨ] (i.e. 'vowel reduction'), but it can also involve raising vowel height, thereby lowering sonority (e.g. in Sri Lankan Portuguese Creole unstressed syllables /æ/→[e], /a/→[ə], and /ɔ/→[o] – Smith 1978, Crosswhite 2000). Such cases can be analyzed using *non-Hd_{PrWd}/*x* or *non-Hd_{Ft}/*x* constraints outranking relevant IDENT constraints (Crosswhite 2000). There are complications with this pattern because unstressed vowels can sometimes become more sonorous; for recent discussion and proposals see Crosswhite (1999, 2004), de Lacy (2006:Ch.7), Harris (2005), and references cited in these works. For discussion of sonority–stress interactions elsewhere (especially with regard to onsets in stressed syllables) see de Lacy (2001) and Smith (2002).

Neutralization also happens for tone and stress. For example, in Lithuanian low tone becomes high in stressed syllables under the influence of *Hd_{Ft}/L: e.g. /prànèʃù/ → [(ˈpránè)ʃù] 'I announce' (Blevins 1993:244, de Lacy 2002a: Sec.4.1).

12.6.2 Deletion

(Non)head-sonority and -tone constraints can also force deletion. For example, when [a] would appear in the non-head of a foot (or perhaps more generally an unstressed syllable), it deletes in Lushootseed (29) (Urbanczyk 1996, Gouskova 2003 Sec.4.6.1). 'RED' is a reduplicative morpheme. The footing in (29) is mine.

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(29) *Lushootseed [a]-deletion in the non-head of a foot (Urbanczyk 1996, Gouskova 2003)*

(a) Delete [a] if it would appear in the non-head of a foot
/RED-caq'/ → [(ˈc̲a̲cq')] 'to spear big game on salt water', *[(ˈc̲a̲caq')]
/RED-walis/ → [(ˈw̲a̲wlis)] 'little frog', *[(ˈw̲a̲wa)lis]
/RED-laq-il/ → [(ˈl̲a̲ʔlqil)] 'be a little late', *[(ˈl̲a̲ʔla)qil]

(b) When deletion is blocked by a cluster condition, reduce to [ə]
/s-RED-ɬagʷid/→[(ˈs-ɬa̲ɬ̲ə)gʷid] 'little mat', *[(ˈs-ɬa̲ɬ̲a)gʷid], *[(ˈs-ɬa̲ɬ̲gʷid)]
/RED-tabəc/ →[(ˈta̲ʔ̲t̲ə)bəc] 'slowly, softly'

(c) Other vowels do not delete
/RED-hiqəb/ → [(ˈh̲i̲hi)ʔəb] 'too, excessively', *[(ˈh̲i̲hʔəb)]
/RED-wiliq'ʷid/ → [(ˈw̲i̲wi)liq'ʷid] 'quiz someone', *[(ˈw̲i̲wli)q'ʷid]

Following Gouskova (2003 Sec.4.6.2.2), this pattern can be modeled by *non-$\mathrm{Hd}_{\mathrm{Ft}}/a$ outranking the anti-deletion constraint MAX. Constraints on footing (e.g. ALIGN-L(Ft,PrWd)) and other faithfulness resolutions (e.g. IDENT[low]) must also outrank MAX (30).

(30) *Lushootseed non-head [a]-deletion*

/RED-walis/	*non-$\mathrm{Hd}_{\mathrm{Ft}}/a$	ALIGN-L(Ft,PrWD)	IDENT[low]	MAX
(a) (ˈw̲a̲wa)lis	*!			
(b) w̲a̲wa(ˈlis)		*!*		
(c) (ˈw̲a̲wə)lis			*!	
☞ (d) (ˈw̲a̲wlis)				*

*non-$\mathrm{Hd}_{\mathrm{Ft}}/a$ outranks IDENT[low] because when deletion is blocked by constraints on consonant clusters (called CLUSTERCOND here), IDENT[low] is violated instead, producing reduction (31).

(31) *Lushootseed non-head [a]-reduction*

/s-RED-ɬagʷid/	CLUSTER COND	*non-$\mathrm{Hd}_{\mathrm{Ft}}/a$	ALIGN-L (Ft,PrWD)	IDENT[low]	MAX
(a) (ˈsɬ̲a̲ɬa)ʷid		*!			
(b) sɬ̲a̲ɬa(ˈgʷid)			*!*		
☞ (c) (ˈsɬ̲a̲ɬə)gʷid				*	
(d) (ˈsɬ̲a̲ɬgʷid)	*!				*

For a detailed analysis, along with discussion of Lushootseed's sonority-driven stress, see Gouskova (2003:Ch.4).

Pulleyblank (2004) provides some examples for tone and deletion from a related but slightly different theoretical perspective.

Non-metrical conditions can also force epenthesis. For example, Alderete et al. (1999 Sec.2.3) argue that Lushootseed /RED-gʷədil/ → [(ˈgʷi̲gʷə)dil] 'sit down' involves epenthesis. The base's [ə] cannot be copied because $^*\mathrm{Hd}_{\mathrm{Ft}}$/ə bans it; so a default vowel is inserted instead – i.e. [ˈi]. An example from New Zealand English is given in note 2. For an example where tone–head interaction forces epenthesis, see Yip (10.3.2) on Mandarin focus and Yip (2002 Sec.3.9) on Mandarin Third Tone Sandhi.

12.6.3 Metathesis and coalescence

The final example (32) shows an extremely complex response to non-metrical conditions in Saanich (a Salish language – Montler 1986).[10] Saanich has lexical stress: the surface position of stress often depends on underlying forms. However, when no morphemes have underlying stress, the output surfaces with a right-aligned trochee: e.g. [kʷ'ə(ˈsinəs)] 'burn one's chest (drinking something hot)', [(ˈmatʃ-ət)] 'aim it'. While penultimate stress is preferred, there is also a desire to avoid stressed schwa, as shown in (32a). When an underlying schwa would receive stress (i.e. appear in the penult), it deletes and the root's vowel (if it is not schwa) moves into the schwa's place. In serial terms: /k'ʷes-ət-əs/ → [k'ʷe(ˈsət-əs)] triggers deletion: [k'ʷe(ˈst-əs)], which triggers metathesis: [(ˈk'ʷset-əs)]. Deletion and metathesis do not occur when a non-schwa appears in penultimate position (32b). A complication is that unstressed vowels reduce to [ə]. This will be discussed below.

(32) *Saanich (Montler 1986)*

(a) Stress avoids schwa through VC metathesis and schwa deletion
/qʷiχʷ-ət-əs/→[(ˈqʷχʷitəs)] 'he missed it' (cf. [(ˈqʷiχʷ-ət)] 'miss it (a shot)')
/k'ʷes-ət-əs/ →[(ˈk'ʷsetəs)] 'he scalded it' (cf. [(ˈk'ʷes-ət)] 'scald it')
/t͡ɬ'ep'-ət-əŋ/ →[(ˈt͡ɬ'p'-etəŋ)] 'it was felt' (cf. [(ˈt͡ɬ'ep'-ət)] 'feel it')
/matʃ-ət-əŋ/ →[mə̱(ˈtʃatəŋ)] 'it was aimed'[11] (cf. [(ˈmatʃ-ət)] 'aim it')
(b) Stress does not avoid other vowels
/k'ʷes-ins/ → [k'ʷə(ˈsinəs)] 'burn one's chest (drinking something hot)' *[(ˈk'ʷsenəs)]
/ʔel-i-ŋ-əɬ/ → [ʔə(ˈlinəɬ)] 'I saved (money, etc.)' (cf. [(ˈʔel-ət)]), *[(ˈʔenəɬ)]
(c) Stress does not avoid schwa when it has no other option
[(ˈp'əl'p'əɬ)] 'hatch a bunch of eggs'
[(ˈχɬ-ət-əs)] 'he hurt him'
[(ˈχʷ t͡ɬ'əqtnətʃ)] 'cougar'

To rule one avenue of explanation out, the morphemes do have underlying schwas. If, for example, the underlying form for 'aim it' [(ˈmatʃət)] is /matʃ-t/ and not /matʃ-ət/, there would be no motivation for inserting [ə] as [tʃt] clusters are permitted on the surface: [qəp'əlitʃt] 'close a box', [tʃtaləs] 'marry', [χələtʃtən] 'twist something'.

While the change in (32a) is complex, it has a straightforward motivation: i.e. $^*\mathrm{Hd}_{\mathrm{Ft}}$/*i*•ə. /k'ʷes-ət-əs/ cannot surface faithfully with penultimate stress as it would violate *Hd$_{Ft}$/*i*•*ə*: i.e. *[k'^{w}e('sətəs)]. The solutions to *Hd$_{Ft}$/*i*•*ə* identified in previous sections are blocked in Saanich. The metrical constraint ALIGN-R (Ft,PrWd) requires penultimate stress, so foot retraction *[('k'^{w}esə)təs] is ruled out. Epenthesis is banned by DEP: *[k'^{w}esə('a̲təs)]. IDENT[F] rules out vowel sonorization: [k'^{w}ə('satəs)]. Finally, deletion is ruled out by MAX: *[('k'^{w}estəs)].

Instead, Saanich responds by coalescence and metathesis. The underlying root vowel and affix /ə/ merge so that: /k'^{w}e$_1$s-ə$_2$t-əs/ → [('k'^{w}se$_{1,2}$təs)]. Coalescence is an essential part of the analysis; if the /ə/ instead deleted, there would be no reason for the root vowel to metathesize with the following consonant (i.e. the outcome should be *[('k'^{w}estəs)]; note that medial [st] is otherwise permitted: e.g. [spes̲t̲ən'əɬ] 'American', [qəʔjəstetʃəl] 'newcomer').

Tableau (33) illustrates this analysis. LIN(earity) bans metathesis, and UNIF(ormity) bans coalescence.

(33) *Sonority-driven metathesis in Saanich*

/k'^{w}e$_1$s-ə$_2$t-əs/	*Hd$_{Ft}$/*i*•*ə*	ALIGN-R (Ft, PrWd)	MAX	DEP	LIN	UNIF
(a) k'^{w}ə('sətəs)	*!					
(b) ('k'^{w}esə)təs		*!				
(c) ('k'^{w}estəs)			*!			
(d) k'^{w}esə('t̲atəs)				* *!		
☞ (e) ('k'^{w}se$_{1,2}$təs)					*	*

There are other candidates to be ruled out. For example, the candidate *[('k'^{w}e$_{1,2}$stəs)] can be ruled out by preventing morphemes from splitting (in this form the affix's /ə/ is not adjacent to its /t/). In the winner [('k'^{w}se$_{1,2}$təs)] /ə/ effectively takes on [e]'s features, so feature change without metathesis (i.e. *[k'^{w}sə$_1$('setəs)]) must be ruled out (probably by OI-∃IDENT[F], which requires every output segment to have the same features as some input segment – after Struijke 2000a). Finally, *[('k'^{w}estə$_{2,3}$s)]) with coalescence of the two suffix schwas must be ruled out, probably by a restriction on coalescence of segments of different affix classes.

Metathesis (movement of a segment to the metrically prominent position) is a rare response to sonority requirements. However, it is a fairly common response for tone, as discussed by Yip (10.3.2) (also see Goldsmith 1987, Downing 1990, 2003b, Bamba 1991, Bickmore 1995, de Lacy 2002a Sec.3).

12.7 Conclusions

This chapter has focused on a theoretical device that combines markedness hierarchies (i.e. sonority and tone) with prosodic heads and non-heads to form constraints. This approach was compared with representational ones which seek to account for the range of behaviour documented above by appealing to either differences in moraic content or sparseness of featural structure; representational approaches were argued to be inadequate.

The theory relates many disparate areas of research, including markedness theory, tone, sonority, and the influences on the form and position of metrical structure (and in fact, all levels of the prosodic hierarchy). In terms of empirical phenomena, it shows that there is a common motivation behind many cases of neutralization (i.e. vowel reduction and raising), deletion, epenthesis, metathesis, and location of prosodic constituents; furthermore, its influence was argued to extend throughout the prosodic hierarchy.

As with any area of research, many questions remain to be answered. At a fundamental level, if a functionalist approach to phonology is assumed (e.g. Gordon Ch.3), what is the motivation for sonority- and tone-driven stress? Is the same functional factor responsible for the similar effects seen in all the different empirical phenomena discussed above? For some recent discussion along these lines, see Gordon (1999, 2002b, 2004) and Ahn (2000). In contrast, if a formalist approach is assumed, one might expect a small number of mechanisms (e.g. constraint schemata) to be able to account for all the patterns identified here (as hinted at here).

The empirical generalizations for many of the phenomena discussed here have emerged only recently. In contrast to areas such as syllable structure, metrical stress, and tone, there is a rather small empirical base to areas like sonority-driven deletion, epenthesis, stress, and metathesis. However, the amount of research in this area is increasing rapidly, as is work on much more well-known areas such as vowel reduction and the influence of prosodic structure on tone.

Notes

My thanks to José (Beto) Elías-Ulloa, Kate Ketner, Michael O'Keefe, and Laura McGarrity for their comments.

1 Structural elements such as onsets and non-moraic codas may also influence prosodic structure, but they will not be discussed here due to lack of space (see Everett & Everett 1984, Davis 1985, 1988b, Halle & Vergnaud 1987, Everett 1988, Goedemans 1993, 1998, Hayes 1995:Ch.7, de Lacy 1997, 2001, Rosenthall & Hulst 1999, Gordon 1999, to appear, Smith 2002, Hajek & Goedemans 2003, McGarrity 2003, Elías-Ulloa 2005, Topintzi 2006 and others cited in these works).

2 There is no particular reason to consider the vocalic and consonantal parts of the sonority hierarchy as separate. The prediction is that stress should avoid consonants with even more vigor than central vowels. For example, in my dialect of New Zealand English, [ə] is allowed in main stressed syllables (e.g. ['pən] ‘pin’, ['bəɾə] ‘bitter’), but consonants

are not. In fact, stress actively avoids consonants through epenthesis: /ejbl/ 'able' surfaces as ['ej.bɫ̩], but when main stress would shift onto the [l] in suffixation, a vowel is inserted: /ejbl-əti/ 'ability' → [ə.'bə̠.lə.ɾi], *[ə'.bɫ̩ .ə.ɾi]).

3 There is evidence from phenomena such as vowel reduction that mid-high vowels (e.g. [e o]) are distinct from mid-low vowels (e.g. [ɛ ɔ]) in sonority. As there are no known stress systems that make this distinction, I will omit it for convenience.

4 See Gouskova (2003) for the view that there is no constraint against every hierarchy element (or, in Fixed Ranking terms, against the least marked element) For the opposing view, see de Lacy (2006 Sec.8.7.3).

5 The winner could be [ka('na.o)riɡ] if Align-R(Ft,PrWd) outranks Iamb. As there is no phonetic realization of foot boundaries, there is no way to tell which ranking is correct in Takia. See Section 12.3 for further discussion of the interaction of metrical structure and sonority. Thanks to José Elías-Ulloa and Laura McGarrity for raising this point.

6 As FtBin must outrank a faithfulness constraint which in turn must outrank all foot-locating constraints, no winner can have a degenerate foot in Takia, so candidates like [ifi('ni)] were not considered.

7 The lack of a $^*\mathrm{Hd}_{\mathrm{Ft}}$/a constraint raises the question of *why* such a constraint cannot exist. The answer is beyond the scope of this chapter; it derives from general theories of markedness and its relation to constraint form (Prince & Smolensky 2004, de Lacy 2002a, 2006).

8 Halle & Vergnaud (1987) also analyze stress systems which refer to features other than weight or edges. In a sense, their proposal is to employ a combination of a metrical and prominence grid: syllables project gridmarks based on their internal properties, both moraic and non-moraic. As with Hayes' (1995) approach, Halle & Vergnaud's theory did not restrict the form of such rules.

9 José Elías-Ulloa raises the issue of whether the non-head constraints refer to consonants as well as vowels. If they did, the most harmonic unstressed nucleus would be one that contains a stop. Similarly, neutralization could force unstressed nuclei to become liquids or nasals. Given the relative rarity of languages that permit non-vocalic nuclei, it is not clear that this prediction is obviously wrong.

10 My thanks to Timothy Montler for discussing the details of Saanich with me.

11 The first schwa in [mə̠ ('tʃatəŋ)] is epenthetic, motivated by a general condition banning word-initial clusters of a sonorant+C.

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