

10 Tone

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10.1 Introduction

By some estimates as many as 70% of the world's languages are tonal. They include languages spoken by huge numbers of people, and in geographically diverse countries – Mandarin Chinese (885 million speakers), Yoruba (20 million), and Swedish (9 million) are all tonal. There are certain areas of the world where almost all the languages are tonal, such as sub-Saharan Africa, China, and Central America.

A language is a 'tone language' if the pitch of the word can change the meaning of the word. Not just its nuances, but its core meaning. In Cantonese, for example, the syllable [yau] can be said with one of six different pitches, and has six different meanings:

- (1) *[yau] in Cantonese*
- | | | | |
|----------------|---------|-------------|----------------|
| high level | 'worry' | high rising | 'paint (noun)' |
| mid level | 'thin' | low level | 'again' |
| very low level | 'oil' | low rising | 'have' |

In other languages, the only thing that matters is that the distinctive pitch of a word appear somewhere in that word, but its exact location may change depending on the morphology of the complex word, and the surrounding phonological context. In Chizigula, a language spoken in Tanzania [Bantu]¹ (Kenstowicz and Kisseberth 1990), some words have all syllables low-toned, like the various forms of the verb /damap/ 'to do', whereas others have one or more syllables with a high-tone, as in the syllables marked with acute accents in the forms of the verb /lombéz/ 'to request'. It is possible to show that the syllables with low tones are not phonologically specified for tone, so they will be called 'toneless' here.

- (2)
- | <i>Toneless verbs</i> | | <i>H-tone verbs</i> | |
|-----------------------|------------------|--|-----------------------|
| ku-damap-a | 'to do' | ku-lombéz-a | 'to request' |
| ku-damap-iz-a | 'to do for' | ku-lombe [́] z-é [́] -a | 'to request for' |
| ku-damap-iz-an-a | 'to do for e.o.' | ku-lombe [́] z-ez-á [́] -a | 'to request for e.o.' |

The high tones are part of the lexical entry of certain verb roots, like /lombéz/ 'request', but

¹ After a language name, square brackets identify the language's affiliation (see <http://ethnologue.com> for further information).

they show up on the penultimate syllable of the complex verb form, and not necessarily on the verb root itself. Nonetheless, the tone is always there somewhere, and distinguishes high tone verbs from toneless verbs like /damap/ 'do'. This chapter is about languages like Cantonese and Chizigula, which are called 'tone languages', or more precisely 'lexical tone languages', and the phonological representation and analysis of their tonal systems.

Before we continue, we need to distinguish three terms that feature in any discussion of tone: fundamental frequency (F_0), pitch and tone. F_0 is an acoustic term referring to the frequency of the signal measured in Hertz (Hz) where one Hertz is one cycle per second. The next term, pitch, is a perceptual term: is it heard as high or low? Very small F_0 differences may not be enough to result in the perception of pitch differences. Pitch can be a property of non-speech signals too: we talk of a high-pitched scream, bird-call, or squeal of tires. Tone, on the other hand, is a linguistic term. It refers to a phonological category that distinguishes two words or utterances, and is thus a term only relevant for languages in which tone plays some sort of linguistic role. Hyman (2001a) has proposed the following definition of a tone language (also see Welmers 1973):

(3) *Definition of a tone language*

A language with tone is one in which an indication of pitch enters into the lexical realization of at least some morphemes.

This definition is designed to include accentual languages like Japanese or Lithuanian (Blevins 1993) as a sub-type of tone language, in which words have one tone (or several) or no tones, and the tone is associated with a particular syllable or mora.

10.1.1 A descriptive summary

Before we look at tonal systems, we need to know how to 'read' them. Unfortunately there is no consensus on how to transcribe tones, and different parts of the world have developed different systems well-suited to their own areas. Africanists have traditionally used a set of accent marks to convey tone, while Asianists have used digits (where 5=high and 1=low), and Meso-americanists have used digits, but where 1=high and 5=low! The following chart may be a useful reference; note that Asianists normally use two digits to show the pitch at each end of the syllable.

(4) *Tone symbols*

| | | <i>Africa</i> | | <i>Asia</i> | <i>Central America</i> |
|--------------------------|----|------------------|--------------------|-------------|------------------------|
| High tone | H | acute accent | á | 55/5 | 1 |
| Low tone | L | grave accent | à or unmarked a | 11/1 | 5 |
| Mid tone | M | level accent | ā or unmarked a | 33/3 | 3 |
| Fall from high to low | HL | acute plus grave | â | 51 | 15 |
| Rise from low to high | LH | grave plus acute | ǎ | 15 | 51 |

Lastly, downstep (a lowered high tone) is traditionally shown by an exclamation point before the downstepped syllable or its vowel, as in [á!ká] for a word with a high followed by a downstepped high. In the IPA, downstep is marked by a superscript down arrow [ˈ].

With this behind us, what kinds of tonal systems have been discovered so far? There are three questions we can ask: what is the tonal inventory of the language, how do tones change in context, and are the tonal facts influenced in any way by segmental factors such as voicing?

10.1.2.1 Tonal inventories

I start with the range of tonal contrasts that a language may have. First, it is possible to contrast up to four (Mambila – Connell 2000) and probably five (Bencnon – Wedekind 1983) different level tones. The most widespread systems are two tone languages such as Haya (Hyman and Byarushengo 1984) or Dagaare [Gur] (Antilla and Bodomo 1996) and three tone languages such as Yoruba [Benue-Congo] (Akinlabi 1985, Pulleyblank 1986). Five-tone ones are very rare. Phonetically, a language may have far more differences as a result of processes like downstep, a common process which lowers high tones after an overt or covert low tone, so that a /H L H/ string is phonetically more like [H L M]. The inverse, upstep, also exists (IPA [ˈ]). For some proposals on how to handle downstep and the related process of downdrift, see Clements (1979), Huang (1980), Truckenbrodt (1998, 2000). Nonetheless, such a language only contrasts two tones, H and L.

Apart from level tones, languages may also have contour tones (rising or falling tones), and a language can have at least two and perhaps three tones of one shape (rising or falling). These typically are found only if there is already a level tone contrast. Falls are much more common than rises (Zhang 2000). Some tones that appear to be non-level may nonetheless be phonologically level. Many Asian languages have a low tone transcribed as 21, but the falling portion is transitional, allowing the voice to descend to the bottom of its range. When a language is reported to have a contour tone, one must also ask where this contour is found. There are three main possibilities. It may be found only on polysyllables, so that each syllable is essentially level, with the first high and the last low, but the word as a whole has a fall. The second possibility is that a contour may occur within a single syllable,

but only if that syllable is heavy (a long vowel or closed syllable), and thus contains two moras, each of which may be assumed to bear a level tone. The third possibility is that contours may occur on any syllable, light or heavy, in which case we are dealing with a true contour tone. Note also that contours are quite often restricted as to where in the word the syllable must be located. Language after language allows contours only on the word-final syllable, probably because it is frequently lengthened.

10.1.2.2 Tonal alternations

The second question to be resolved is how to represent tonal changes in context. In some languages, such as Cantonese, underlying tones change little if at all, but in others they may move, delete, or alter. The environments in which changes take place can be divided into two main types.

First, a change may be caused by a specific local tonal context, as in many Bantu languages, Mandarin, Yoruba and Chinantec. The well-known Meeussen's Rule in Bantu is of this sort: if two H tones become adjacent, the second one deletes. In Mandarin, if two L tones become adjacent, the first one changes to a LH rise. Both of these can be seen as caused by the Obligatory Contour Principle (OCP), as we shall see in section 3.3. In Yoruba (Akinlabi and Liberman 2000), a vowel with an underlying L tone surfaces with a HL contour if a H precedes, and a vowel with H surfaces with an LH if L precedes. Chinantec has a rather similar process (Silverman 1997b). In both cases the tone of the first syllable persists on into the start of the next syllable, in a sort of assimilation.

Second, a change may be caused by positional and/or prosodic factors, as in Shanghai, Chizigula, Trique and Min. In Shanghai, tones that are not in the head syllable of the word delete. In Chizigula, H tones migrate to the penultimate syllable, which is probably the word head. In San Juan Copala Trique (Hollenbach 1977), there is an eight-way tone contrast on final syllables, but usually none on non-final syllables. It is clear that the reason the final syllable can carry tone is because it is the head: final syllables are the only ones that support segmental contrasts such as vowel length, nasal vowels, fortis onsets, and laryngeal codas, and are the location of phrasal stress. In Min, every tone has two variants, one of which occurs in head position and the other in non-head position.

10.1.2.3 Segmental influences

The third question was about segmental interference. Pitch differences are primarily achieved by varying the tension in the vocal folds, and adjusting the height of the larynx (Ohala 1978, Hirose 1997). The vocal folds are also responsible for voicing, and as a result there is a connection between voicing and pitch with voiced obstruents lowering pitch and voiceless obstruents raising it. In some languages voiced obstruents noticeably interfere with tonal changes by lowering the pitch of the adjacent vowel. Such consonants are called depressor consonants. A striking example in which this effect has become phonological is found in Songjiang, a Wu dialect of Chinese.

(5) *Songjiang tones*

| | | | | | |
|----|----|-----------|----|----|-------------------|
| ti | 53 | ‘low’ | di | 31 | ‘lift’ |
| ti | 44 | ‘bottom’ | di | 22 | ‘younger brother’ |
| ti | 35 | ‘emperor’ | di | 13 | ‘field’ |

The words in the right-hand column, which begin with a voiced obstruent, have lowered versions of the pitches of the words in the lefthand column, which begin with a voiceless obstruent. In some languages this difference persists even after the voicing contrast in the obstruents is lost, giving rise to a purely tonal contrast, a process known as tonogenesis. Tone can also interact with other laryngeal properties, such as glottalization and aspiration. In some languages certain tones are associated with particular voice qualities, usually called register. Sometimes the difference is clearly laryngeal, as in Sedang and Chong (Silverman 1996, 1997a, Smith 1968), but sometimes it is pharyngeal, involving the tongue root, as in Cambodian (Gregerson 1976). Finally, there are some instances of correlations between tones and vowel quality (mainly vowel height). See Yip (2002:31) and Dimmendaal and Breedveld 1986 for discussion.

This brief sketch gives us a sense of what a phonology of tone will have to look for and explain. Now we turn to the formal statement of these processes.

10.2 A theoretical framework for tone

10.2.1 Distinctive features of tone

There have been many different attempts to formulate a satisfactory set of features for tonal contrasts. The right system must (i) define four, perhaps five, contrastive levels, (ii) define two (or three) rises and falls, (iii) relate these to laryngeal contrasts, especially voicing, (iv) handle downstep, and (v) simply characterise the observed tonal alternations. There is no consensus at present, but one fairly popular model uses two binary features, [\pm Upper] for tonal register, which subdivides the pitch range of the voice into two parts, and [\pm high] for a finer-grained subdivision of each part into two sub-parts. Four levels can thus be captured as shown below:

| | | | | |
|-------|--------|-------|-----|------------|
| (6) | +Upper | +high | 55 | extra-high |
| | | −high | 44 | high |
| | ----- | | | |
| | −Upper | +high | 33 | mid |
| −high | | 11 | low | |

n-ary systems have also been suggested, such as Tsay (1994), but these have two problems: there is no upper bound to the number of tones, and they define no natural classes. Consider a simple assimilation in Yala (Nigeria – Bao 1999, using data from Armstrong 1968). In Yala, H becomes M after M or L. If M and L are both [–Upper], this is simply explained as the spreading of [–Upper] in a binary Register system, but for Tsay the conditioning environment of M and L must be simply the list [1-2P], where the digits refer to the level and

P stands for pitch. In this approach, there is no explanation as to why the output is M, rather than L.

These features may be related to each other and to the laryngeal features that define voicing, aspiration and glottalization in a feature geometry that is still disputed. For various proposals and discussion see Halle and Stevens (1971), Yip (1980), Clements (1981), Yip (1989), Bao (1990), Duanmu (1990, 1994), Hyman (1993), Snider (1990, 1999), and Hall [ch.12]. In practice, most work on tonal phonology skirts the issue of the features, and represents tones as H, M, L or with digits, and I shall follow this practice in this chapter unless otherwise stated.

In addition to the number of tones that can be expressed by a given feature system, when one is dealing with level tones it is often possible to show that one surface tone is not in fact specified phonologically since it is inert, and does not participate in any active way in alternations. If the feature system contrasts (n) tones, (n+1) surface contrasts can thus be captured. In a two tone system, the unspecified tone is usually but not always the low tone, so that the surface high-low opposition is phonologically a H vs. Ø one. Occasionally this is reversed, so that the underlying contrast is L vs. Ø: see Hyman (2001b) for an excellent recent summary.

One issue from early on was whether contour tones should have a feature like [+rise], or whether they were really sequences of level tone targets, LH. Here the evidence is clear: at least some contour tones must be analyzed as sequences of level tones because they can be seen to be derived from that source. In Hausa (Newman 1995, Jagger 2001), some words have two variants, bi-syllabic and mono-syllabic. If the bisyllabic word is HL, then the monosyllable has a fall. If the fall is analyzed as simply a HL on a single vowel, then we can understand this as vowel deletion, with retention and reassociation of the remaining tone: *míni or mìn* ‘to me’. In Cantonese there is a widespread phenomenon known as changed tone (Yip 1980). In one sub-type, there are alternations between certain specific morphemes with high tone, such as /yat5/, and forms in which the segments delete, but the tone remains behind and attaches to the preceding morpheme. If that morpheme has a low or mid tone, as here, the result is a rise from low or mid to high: yat5 tiu21 yat5 tiu21 ~ yat5 tiu25 tiu21 ‘one-strip-one-strip (strip by strip)’.

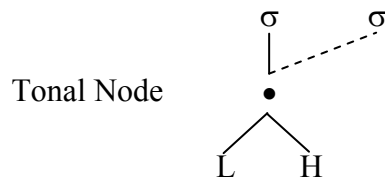
At the same time it must be said that contours sometimes behave as units. Arguments come from both phonetic data and phonological behavior. Xu and Wang (2001) have argued that the phonetic targets in Mandarin are trajectories, not levels. Phonologically, Changzhi has a diminutive suffix /tə(?)/, with no tone of its own. It acquires its tone by the copying or spreading of the entire complex tone of the preceding root (but see Duanmu 1994 for a dissenting view):

- (7) *Changzhi whole tone copying*
- | | | |
|--------|-------|------------|
| tsə213 | tə213 | ‘cart’ |
| paŋ535 | tə535 | ‘board’ |
| xə24 | tə?24 | ‘child’ |
| ɕiaŋ53 | tə?53 | ‘fillings’ |

This paradox has led to models in which the tonal features form part of a tree-geometric representation, with a tonal node dominating the LH sequence. This node can then spread,

giving the unitary contour behavior. (See next section on the association of tones to syllables.)

(8) *Contour tone spreading as a unit*



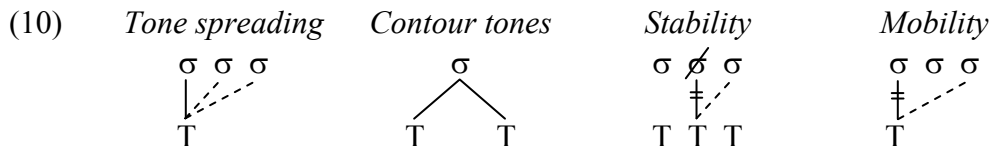
10.2.2 *The autosegmental behavior of tone*

The second issue as we ask how tone is represented relates to how it changes in context. Tone is notorious for its independence from the segments on which it is realized, (something that Firth 1948 and Pike 1948 were well aware of) and this fact led Goldsmith (1976) to propose that it be represented autosegmentally, on a separate tier from the segments but linked to them by association lines. The associations between tone and the Tone-Bearing Units (TBUs) were governed by a set of well-formedness conditions.

(9) *Well-formedness conditions*

1. Every TBU must have a tone.
2. Every tone must be associated to some TBU.
3. Association proceeds one-to-one, left-to-right.
4. Association lines must not cross.

The conditions allow tones to spread to more than one segment, and conversely they allow a segment to have more than one tone, forming a contour. It has another consequence: tone can exist in the absence of a segmental host. This can arise in two ways: either the underlying lexical entry contains an unaffiliated tone - a floating tone - or segments may delete, leaving their tone behind either floating, or reassigned to another segment. This last phenomenon is known as stability. A related effect of the separate tiers for segments and tone is found when segments copy, but tones do not. Finally, tones can change affiliations, moving off their host onto another segment: this is called mobility. In the diagrams below broken lines denote new affiliations, solid lines are underlying ones. Tones are shown associated to the syllable node (see below).



All of these behaviors are found. In Chilungu [Bantu] (Bickmore 1996), there is unbounded H spread from the infinitival prefix /kú-/ to all except the last syllable of the verb. In Siane nouns [Highlands, Papua New Guinea] (James 1994), contours are formed when excess

tones have nowhere else to go. A monomoraic noun with two underlying tones shows up with only one tone on the noun root, and the second tone on any suffix. Only if there is no suffix do the two tones surface on the noun itself, forming a contour. In Cantonese (Yip 1980), as we have seen, there are alternations between morphemes with high tone and forms in which the morpheme deletes, but the tone remains behind and attaches to the preceding morpheme. In Shona (Odden 1984, Downing 2003) segments reduplicate but tones do not. In Chizigula [Bantu] (Kenstowicz and Kisseberth 1990), H tone migrates from the verb root to the penultimate syllable of the word. It may thus end up three or more syllables away from its source.

It is not always clear whether tones associate to segments, syllables or moras. In the case of a language with only mono-moraic, open CV syllables, where each syllable bears exactly one tone, the TBU could be the vowel, mora or syllable. If the language has syllabic nasals which bear tone, but onset nasals which do not, we can rule out the segment as TBU, since the prosodic affiliation of the segment determines its TBU status. This leaves the mora (or the syllable rhyme) as the possible TBUs: nasals that have moras or rhymes will bear tone, but morales onset nasals will not. If the language has both light mono-moraic and heavy bi-moraic syllables, and if these differ in the number of tones they can bear, so that mono-moraic syllables can have only one tone but bi-moraic syllables can have two, then it must be the case that the TBU is the mora, not the syllable. There are languages in which the TBU is not just any mora, but vocalic or sonorant moras only. See Zec (1988) and Steriade 1991 for discussion. Lastly, if the two different syllable weights can bear the *same* number of tones, then the syllable must be the TBU. Since there are cases in which the TBU *must* be the mora or the syllable, and no cases in which it *must* be the segment, it seems that tone always associates to prosodic entities, but languages can differ as to whether the syllable or the mora is the TBU.

The machinery of autosegmental phonology, although originally devised for tone and ideally suited to it, has been co-opted for other phenomena such as harmony (nasal and vowel), and local assimilations. See Archangeli and Pulleyblank [ch.15] and Baković [ch.14] for details.

10.2.3 The formal representation of tonal alternations

When tones are placed in context, they may change in a variety of ways. The causes of change are varied. One of the most common is prosodic structure: tones (especially H tones) tend to be attracted to prominent positions, such as stressed syllables and word edges. Conversely, non-head positions such as unstressed syllables may reject tones, resulting in tone deletion or tone lowering (the analogy here is vowel reduction to schwa). A different cause of change is the local tonal context: a tone may spread onto a span of toneless syllables, or onto a neighboring toned syllable to create a contour, or it may assimilate to or dissimilate from an adjacent tone.

In Optimality Theory (Prince and Smolensky 1993, Kager 1999), the pressures that typically cause tonal change are stated as markedness constraints that dominate faithfulness constraints and thus force changes to take place. These include general markedness constraints relating to tonal features, constraints that deal with associations between tones and the tone-bearing units (roughly Goldsmith's well-formedness conditions, in OT form),

constraints that regulate tones in context (such as the OCP), constraints that regulate the mutual influence of tone and prosody, and constraints that assess the positioning of tone within some prosodic or morphological unit. These markedness constraints interact with faithfulness constraints that penalize deletion, insertion, feature change, and movement or spreading (by addition or removal of association lines). As in any other area of phonology, these may apply to input-output relations, base-reduplicant relations, or output-output pairs.

I will illustrate the interaction of some of these constraints with several case studies. Section 3.1 shows how basic association patterns in Mende can be explained. Section 3.2 looks at tone-prosody interaction, and section 3.3 shows the way that local tonal changes can be handled. Constraints will be introduced and defined as they are needed.

10.3 Case studies and exemplification

10.3.1 *Mende tone association*

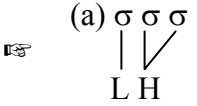
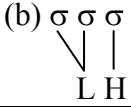
The West African language Mende, a language first studied theoretically in influential work by Innes (1969) and Leben (1973), is frequently used to exemplify the workings of autosegmental phonology. It has two tones, H and L, and in general they associate one-to-one with syllables from left to right across the word. When there are fewer tones than syllables, the final tone spreads to the remaining syllables to create a plateau. When there are more tones than syllables, the excess tone associates to the final vowel to form a contour.

This one-to-one left-to-right mechanism immediately offers an explanation for the very common pattern in which languages only allow contours at the ends of words. However, in a non-derivational theory like OT, we cannot resort to a step-by-step left-to-right procedure. Instead, the obvious counterpart is to use left alignment, ALIGN-L (Tone, PrWd), requiring each tone to stay as close to the left edge of the prosodic word as possible. Each tone is assigned an asterisk for each TBU that intervenes between the one it is associated to, and the left edge of the word.

While this works fine in the case of fewer tones than TBUs, it fails when there are more tones than TBUs. The following two tableaux illustrate this point. The sad face ☹ marks the winner as chosen by the grammar, but wrongly so. In the first tableau, candidate (a) wins because H is only one syllable from the left edge, whereas in (b) it is two syllables away.

(11) *Fewer tones than TBUs*

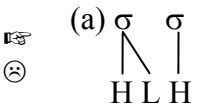
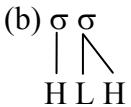
ALIGN-L correctly chooses (a), with a plateau at the right edge

| /σ σ σ/ L H | ALIGN-L |
|---|---------|
| (a)  | * |
| (b)  | * *! |

In the next tableau, (a) will wrongly win because only one tone fails to attach to the leftmost syllable. Candidate (b) incurs two violations of ALIGN-L: one because the L tone is one syllable away from the left edge, and one because the second H tone is one syllable away from the left edge.

(12) *More tones than TBUs*

ALIGN-L incorrectly chooses (a), with a contour at the left edge

| /σ σ/ H L H | ALIGN-L |
|---|---------|
| (a)  | * |
| (b)  | * *! |

Zoll (1997, 2003) points to an empirical problem with attributing the distribution of contours solely to left-to-right association. In many languages contours can arise from other sources, such as vowel deletion, and even these contours may be disallowed and eliminated non-finally. In Ohuhu Igbo (Clark 1983), falling tones can be created word finally on the subject of an affirmative sentence by the addition of a floating low tone: /ékwé/ → [ékwê]. Medially however, spreading rules are not allowed to create contours, and instead the original tone on the target syllable de-links: in this example the H of the first syllable spreads onto the second syllable, but instead of creating a fall the original L delinks: /éwèlàghì/ → [éwèlàghì] *[éwèlàghì]. The underlined portions are the affected syllables.

Let us look at Mende again. Consider these basic noun patterns, taken from Zoll's work with slight adaptations in tone transcriptions. In general, they follow the left-to-right pattern.



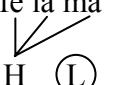
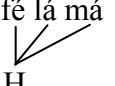
(13) *Tone patterns in Mende nouns* (Zoll 2003:231)

| | σ | | $\sigma\sigma$ | | $\sigma\sigma\sigma$ | |
|-----|----------|-------------|----------------|------------|----------------------|----------------|
| H | kó | ‘war’ | pélé | ‘house’ | hávámá | ‘waistline’ |
| L | kpà | ‘debt’ | bèlè | ‘trousers’ | kpàkàli | ‘tripod chair’ |
| HL | mbû | ‘owl’ | ngílà | ‘dog’ | félàmà | ‘junction’ |
| LH | mbă | ‘rice’ | návó | ‘money’ | lèlèmá | ‘mantis’ |
| LHL | mb`â | ‘companion’ | nyàhâ | ‘woman’ | nikìli | ‘groundnut’ |
| HLH | – | | ndéwě | ‘sibling’ | yámbùwú | ‘tree (sp.)’ |

If the constraint ALIGN-L(Tone,PrWd) fails to handle the facts, what is the alternative? Zoll suggests that the avoidance of non-final contours be attributed to a licensing requirement on contour tones stated as ALIGN-R(Contour), requiring any contours to be final. The motivation for this constraint is drawn from widespread evidence that contours, especially rises, are restricted in many languages to final syllables, perhaps because they are often longer: see Zhang (2001) for discussion.

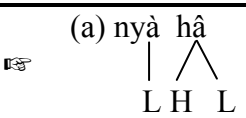
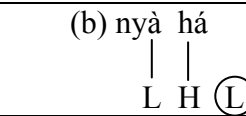
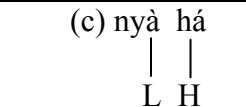
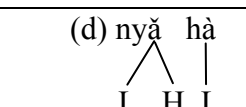
Provided that ALIGN-R(Contour), MAX-T (which prohibits tone deletion) and *FLOAT (which requires all tones to be associated to some TBU) dominate ALIGN-L, we will achieve the desired results. The following tableaux illustrate how this works for the words for ‘junction’ and ‘woman’. The circle round the unassociated L tones in some candidates shows that they are now floating. In the case of fewer tones than syllables, ALIGN-L decides the issue, preferring candidate (14a) with a plateau at the end to candidate (14b) with a plateau at the start.

(14) *Fewer tones than TBUs*

| /felama/ H L | ALIGN-R (Contour) | MAX-T | *FLOAT | ALIGN-L |
|--|----------------------|-------|--------|---------|
| (a) fé là mà  H L | | | | * |
| (b) fé lá mà  H L | | | | **! |
| (c) fé lá má  H (L) | | | *! | |
| (d) fé lá má  H | | *! | | |

However, when there are excess tones the high-ranked ALIGN-R(Contour) decides the issue, over-ruling alignment and choosing (15a) over (15d).

(15) *More tones than TBUs*

| / nyaha / L H L | ALIGN-R (Contour) | MAX-T | *FLOAT | ALIGN-L |
|---|----------------------|-------|--------|---------|
| (a)  | | | | * * |
| (b)  | | | *! | * |
| (c)  | | *! | | * |
| (d)  | *! | | | * |

Zoll's proposal has the further advantage that unlike left-to-right association it explains the contour shift that happens in cases like (16). Based on other data, Zoll argues that tone association in (16) is cyclic, so that /HL/ must be associated with /mbu/ before the suffix is added. After suffixation, the contour is non-final, in violation of ALIGN-R(Contour), which triggers reassociation.

$$(16) \quad \begin{array}{c} \text{/mbu} \quad \text{-i/} \\ \diagup \quad | \\ \text{H} \quad \text{L} \quad \text{H} \end{array} \quad \rightarrow \quad \begin{array}{c} [\text{mbu} \quad \text{-i}] \\ | \quad \diagup \\ \text{H} \quad \text{L} \quad \text{H} \end{array}$$

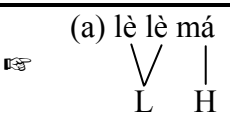
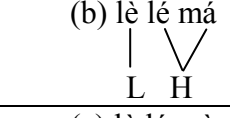
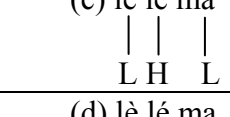
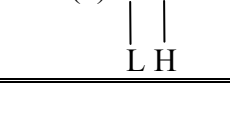
Lastly, she points out that left-to-right association, and also ALIGN-L, make the wrong prediction for /LH/ on trisyllables. We expect LHH, but actually get LLH. Zoll attributes this to a constraint against adjacent H toned syllables, *CLASH:

(17) *CLASH: No adjacent syllables linked to prominent tone, i.e. H

Crucially for Zoll, *CLASH does not care whether there are two H tones (one per syllable), or only one shared tone. It is thus much more powerful than the OCP. SPECIFY and DEP-T dominate *CLASH, so a single /H/ survives, and can spread to all syllables. For further details of how *CLASH works the reader is referred to Zoll (1998).

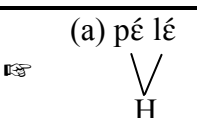
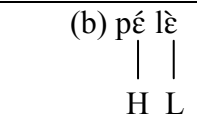
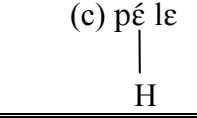
We can also establish the rankings of *CLASH and ALIGN-L, as well as SPECIFY (which requires every TBU to have a tone) and DEP-T (which prohibits tone insertion), as can be seen from the tableaux for the words for 'mantis' and 'house'. The grammar we need is SPECIFY, DEP-T » *CLASH » ALIGN-L. In the tableau below, candidate (a), with the high tone associated to the final syllable, incurs two violations of ALIGN-L, but still wins out over candidates (b) and (d), with only one violation each, showing that SPECIFY and *CLASH must be higher ranked than ALIGN-L.

(18) *Trisyllables with high sequences*

| / le le ma / L H | SPECIFY | DEP-T | *CLASH | ALIGN-L |
|---|---------|-------|--------|---------|
| (a)  | | | | * * |
| (b)  | | | *! | * |
| (c)  | | *! | | * * * |
| (d)  | *! | | | * |

In the final tableau below, we see that *CLASH may be violated if the underlying representation contains only one tone. Candidate (a), which violates *CLASH because two adjacent syllables are both high, wins out over candidate (b), which has inserted a low tone in violation of DEP-T, showing that DEP-T must be higher ranked than *CLASH.

(19) *Surface violations of *CLASH*

| / pɛ lɛ / H | SPECIFY | DEP-T | *CLASH | ALIGN-L |
|---|---------|-------|--------|---------|
| (a)  | | | * | |
| (b)  | | *! | | * |
| (c)  | *! | | | |

Zoll's analysis for Mende basic tone association, using alignment and positional markedness in conjunction with SPECIFY and *FLOAT, can be extended to a wide range of languages. I now turn to interactions between tone and prominence.

10.3.2 *Tone - Stress interaction*

It is very common for tone and stress to interact. One of the most widespread phenomena is the loss of all tonal contrasts in unstressed position, in much the same way that unstressed vowels neutralize to schwa in English. In Shanghai (Duanmu 1993), non-initial (i.e. non-

head) syllables become toneless, but then the two tones of the initial syllable readjust themselves to cover the first two syllables:

(20) *Shanghai stress-tone interaction*

| | | | |
|-------------|---|-------|----------------|
| se52 + pe52 | → | 55 21 | ‘three cups’ |
| se52 + bə23 | → | 55 21 | ‘three plates’ |
| sz34 + pe52 | → | 33 44 | ‘four cups’ |
| sz34 + bə23 | → | 33 44 | ‘four plates’ |

Any subsequent syllables also lose their tone, and do not acquire any from the initial syllable. They surface as low, no matter what the tone of the preceding second syllable. Since they are invariantly low, it seems best to assume that they are supplied with a phonological L tone before the phonetics

Like vowel reduction (Beckman 1997), this can be analyzed as the result of markedness pressures, outranked by positional faithfulness in head position, captured by the constraint HEAD-MAX(T), prohibiting deletion of tones in head position. This must outrank the general markedness constraint *TONE, which in turn must outrank general tonal faithfulness, so the grammar will have HEAD-MAX-T » *TONE » MAX-T. In the tableau below, candidate (c) deletes even the head tones, in violation of HEAD-MAX-TONE. Candidate (b) keeps all the tones, incurring massive violations of tonal markedness *TONE. Candidate (a) wins because it keeps all and only the head tones. Heads are underlined.

(21) *Loss of non-head tones in Shanghai*

| /sz34 + pe52/ | HEAD-MAX-T | *TONE | MAX-T |
|-----------------------|------------|----------|---------|
| (a) <u>sz</u> 3 pe4 | | * * | * * |
| (b) <u>sz</u> 34 pe52 | | * * * *! | |
| (c) <u>se</u> pe | * *! | | * * * * |

More complex systems like Wenzhou (Yip 1999) reduce the set of contrasts on non-heads, but do not entirely obliterate them.

A second well-known interaction is the attraction of tones to head position in the word or phrase (Goldsmith 1987). In many languages, a word has only one tone or tonal complex on the surface, and it is found on the head no matter where it originates lexically. For example, in Chickasaw the tones of pitch accents are attracted to the head syllable of a phrase (Gordon 2003), and in many Bantu languages (like Chizigula mentioned earlier), they are attracted to the head syllable of the word, the penultimate syllable, which is also lengthened. The position of the head may be predictable, or lexically specified. When tones are sparsely distributed in this way, the language is sometimes called an accentual language rather than a tone language. (See also Kager [ch. 8] and de Lacy [ch.9]). Formally, we may assume a constraint that attracts tones (usually high ones) to head syllables:

(22) HEAD=H: Head syllables must bear a H tone

This will outrank *ASSOCIATE and *DISASSOCIATE, the faithfulness constraints which ban addition and removal of association lines, and result in tonal shift. SPECIFY must be ranked below *ASSOCIATE to ensure that we get shift, not spreading. Head syllables are underlined.

(23) *Tonal shift to the head syllable*

| /σ σ <u>σ</u> σ/ H | HEAD=H | *ASSOC | *DISASSOC | SPECIFY |
|--------------------------------|--------|--------|-----------|---------|
| (a) σ σ <u>σ</u> σ ↖ H | | * | * | * * * |
| (b) σ σ σ σ ↙ ↘ H | | * * ! | | * |
| (c) σ σ <u>σ</u> σ H | * ! | | | * * * |

Candidate (c), which leaves the tone in place, violates HEAD=H. Candidate (b), with spreading, violates *ASSOCIATE twice, because two new association lines have been added. Candidate (a) also violates *ASSOCIATE, but once only, so it prevails over (b) to win even though it violates both the lowest ranked constraints.

In other languages, there is a preference for stressed syllables to be high. In Mandarin, main stress may be on any tone, including L: mai^L-le ‘bought’. However, emphasis placement is subject to avoidance of a L-toned syllable. In the adjective phrases below, the usual practice is to emphasize the adjective itself, as in the left-hand example. However, if the adjective is low, emphasis shifts off it onto the modifier. The modifier is also low underlyingly, but undergoes a regular tonal rule of Mandarin which changes it to rising in front of another low syllable. As a result, in the output the emphasis falls on the high rising first syllable (Zhang 1988).

- (24) ‘very heavy’ ‘very small’
 hen zhong hen xiao
 L HL L L → LH L

A second way to avoid emphasizing a L-toned syllable is to change the phonological phrasing so that it is grouped with another low-toned syllable, and may thus undergo the change to high rising. This happens under contrastive focus (Shih 1997:112). The normal phrasing is shown on the left, and the contrastively focused phrasing on the right. In the normal phrasing, the syllable meaning ‘buy’ is not phrased with the following syllable, so it does not change to a high rise. When contrastively stressed, the phrasing changes, and it now becomes high rising.

- (25) (a) *Normal phrasing* (b) *Phrasing under contrastive focus*
- only buy stocks only buy stocks not sell stocks
- zhi mai gu-piao zhi mai gu-piao, bu mai gu-piao
- L L L HM L [L L HM MH HM L HM
- (LH L) (L HM) (L) [(LH L)(HM)

Note that if the following syllable is not L, making the tonal change impossible no matter what the phrasing, the focused element becomes the so-called ‘full third tone’, which is longer and with a final mid rise. See also Shen (1990:51).

Formally, we may propose a constraint *FOCUS/L, simply a type of *HEAD/L banning L tone on heads, where the head in question is head of a focus phrase. This dominates various constraints on phrasing, including BINARITY. The following tableau shows the case of ‘only buy stocks’, where emphasis changes the preferred phrasing from (b) to (a):

- (26) *Change in phrasing under focus*

| /L <u>L</u> L HM/ | *FOCUS/L | BIN |
|-----------------------------|----------|-----|
| (a) (L) (<u>MH</u> L) (HM) | | * * |
| (b) (MH <u>L</u>) (L HM) | *! | |

Note that *FOCUS/L doesn't *cause* the tone sandhi rule to apply, otherwise L could become MH even before other tones. Tone sandhi is only triggered by the OCP banning LL sequences within the binary constituent, but *FOCUS/L selects between two different ways of applying it, by forcing a particular constituent structure.

A much less common but also more interesting type of tone-stress interaction can be found in several dialects of Mixtec, where the placement of stress is dependent on the particular tones of the word, not just on the presence or absence of tone. This case is discussed in some detail elsewhere in this volume (see de Lacy [ch.9]), but the essential point is that there is a preference for stressed syllables to be H, and for unstressed syllables to be L. In other words, H is intrinsically more prominent than L. De Lacy posits two constraint hierarchies to capture this, restated slightly here

- (27) *HEAD/L » *HEAD/M » *HEAD/H
 *NON-HEAD/H » *NON-HEAD/M » *NON-HEAD/L

Returning to simpler types of interaction between tone and stress, de Lacy's constraint families can be used for these too. In Shanghai, where all and only head tones survive, we could say that *NONHEAD/H,M,L » MAX-T » *HEAD/L,M,H. And in Bantu languages where H tones are attracted to the head syllable, we could say that *NON-HEAD/H, MAX-T » *DISASSOCIATE, *ASSOCIATE » *HEAD/H.

However, there is a problem in reanalyzing the Shanghai data using de Lacy's positional markedness account as opposed to the positional faithfulness approach offered above in (21). The reason for this is that although the head syllable tones are preserved, they do not actually have to surface on the head syllable. In the last two examples in (20), the rather high tone shown by [4] surfaces on the non-head syllable, in violation of one of the *NONHEAD/T constraints, presumably *NONHEAD/H or *NONHEAD/M. For further

discussion of positional faithfulness vs. positional markedness, see Zoll (1998, 2004).

De Lacy's statements are all negative ones, and one might ask whether positive statements such as the HEAD=H constraint used in the Chizigula analysis in (23) are still needed. If low toned syllables are unspecified for tone, we cannot replace HEAD=H by *HEAD/L and get the same result. However, one could construct an analysis in which *NON-HEAD/H forces the H tones to leave the non-head syllables. Other cases are more recalcitrant. In Mandarin Chinese, contrastive stress avoids L toned syllables, but is freely allowed on H, MH, and HL syllables. The requirement for a H tone must be stated positively, since HL is acceptable. This issue remains somewhat open, but the close relationship between tone and prominence is clear.

I now turn to tone alternations conditioned by neighbouring tones.

10.3.3 Local tone changes and the OCP in Bantu languages

It is common to find tones changing in particular tonal contexts. There are various possible causes of this, including assimilation and dissimilation. One of the most common is pressure from the Obligatory Contour Principle, or OCP, which bans sequences of adjacent identical elements, such as two H tones. This section shows it in action.

Myers (1997) gives an elegant overview of the way the OCP influences tonal phonology, and the remainder of this section is taken from his work. Recall that the OCP bans sequences of adjacent identical elements, in this instance H tones. We shall see that the OCP may be observed (Shona), or violated (Kishambaa); the OCP may force a change in the input, a Faithfulness violation (i.e. trigger a rule) or the OCP may block an otherwise expected change (i.e. block a rule). In the languages under discussion, there is a contrast between H tone and the absence of tone, realized on the surface as low pitch.

The first case is one where the underlying form contains a sequence of H tones, and the OCP causes deletion of the second one. This rule, known as Meeussen's Rule, is widespread in Bantu tonology, and these examples come from Shona. Underlining draws attention to underlyingly H toned vowels, and surface high is shown by an acute accent.

- (28) *OCP-triggered deletion* (Shona: Meeussen's Rule)
 bángǎ 'knife' í-bǎngǎ 'it is a knife'

The noun 'knife' has one doubly-linked H tone underlyingly, and the copula prefix also has a H tone. Attachment of the copula causes deletion of the H on the noun.

The deletion can be captured by the ranking OCP » MAX-T, and the preference for deleting the second of the two tones by including ALIGN-L in the grammar.

(29) *OCP-triggered deletion in Shona*

| /i banga/ / H ₁ H ₂ | OCP | MAX-T | ALIGN-L |
|--|-----|-------|---------|
| (a) i banga / H ₁ H ₂ | *! | | * |
| (b) i banga / H ₂ | | * | *! |
| (c) i banga H ₁ | | * | |

Our second case shows the OCP blocking the usual spreading from a clitic if doing so would create an OCP violation:

(30) *Failure to spread H from clitic (Shona)*

Normal spreading: sadza ‘porridge’ i-sádza ‘it is porridge’
 Spreading blocked: badzá ‘hoe’ i-badzá ‘it is a hoe’ (*i-bádzá)

Let us assume that the spreading is caused by pressure from SPECIFY, and that SPECIFY dominates *ASSOCIATE. The blocking effect will then be caused by the OCP outranking SPECIFY. Lastly, since we do not get spreading followed by deletion (candidate (b)), MAX-T must also dominate SPECIFY. The ranking OCP » MAX-T was justified in the previous tableau.

(31) *OCP » MAX-T » SPECIFY-T » *ASSOCIATE*

| /i badza/ H ₁ H ₂ | OCP | MAX-T | SPECIFY-T | *ASSOCIATE |
|--|-----|-------|-----------|------------|
| (a) i badza / H ₁ H ₂ | *! | | | * |
| (b) i badza / H ₁ | | *! | | * * |
| (c) i badza H ₁ H ₂ | | | * | |

The final way OCP violations are avoided in Shona is by fusion of two H tones into one, which is limited to applying within the part of the verb Myers calls the macrostem, made up of the root and any suffixes, the object prefix, and subject prefixes in the subjunctive,

negative, and participial forms.

(32) *Fusion* (within macrostem only)

(a) tí-téng-és-é ‘we should sell’

Evidence for fusion

Whole sequence deletes by Meeussen’s Rule after the H-toned clitic /há/

(b) há-tì-téng-es-e ‘let us sell’ (*há-tì- téng-és-é)

In (32a), we see that in this environment two adjacent underlyingly H syllables remain high-toned, in apparent violation of the OCP. However, Myers points out that it can be shown that these two syllables are now associated with a single H tone, because if the word is placed in the environment of Meeussen’s rule, as in (b), both of them lose their high pitch. The two underlying tones of /tì-téng/ have thus fused into one. Fusion is a Faithfulness violation, usually stated as a constraint we can call NO-FUSION, so clearly the OCP dominates NOFUSION. Since fusion is preferred to deletion, we must also say that MAX-T dominates NOFUSION. In the tableau below the subscripts simply allow one to track the tones. In the final candidate, the output tone is a fusion of both input tones.

(33) *Fusion (Macrostem)*: OCP » MAX-T » NO-FUSION

| /tì -teng-es-e/ H ₁ H ₂ | OCP | MAX-T | NOFUSION |
|---|-----|-------|----------|
| (a) tí -teng-es-e H ₁ H ₂ | *! | | |
| (b) tì -teng-es-e H ₁ | | *! | |
| (c) tí -teng-es-e H _{1,2} | | | * |

Note that the difference between the macrostem grammar, where fusion removes OCP violations, and the phonological word grammar, where deletion is used, is only in the relative ranking of NOFUSION and MAX-T. Before we leave fusion, it is worth noting that one very common tonal process, tonal absorption, can be viewed as a sub-case of OCP-triggered fusion. Hyman and Schuh (1974) note that in many languages, including Bamileke, Mende, Kikuyu, Hausa and Ngizim, sequences of /HL.L/ become [H.L], and sequences of /LH.H/ become /L.H/. They view this as rightward shift, followed by loss of one of the two identical tones on the second syllable, but it could equally well be fusion of the two tones. No matter which, the OCP is clearly at work here too.

We have seen that Shona and many other languages carefully observe the OCP, but not all languages rank it so highly, as noted by Odden in an influential 1986 paper. For example, in Kishambaa, spreading is not blocked by the OCP (Odden 1982, 1986):

- (34) *Surface OCP violations* (Kishambaa)
 /ní-ki-chí-kómá/ → [níkí-!chíkómá] ‘I was killing it’

Quite generally in Kishambaa H tones are downstepped after another H tone. Since there is downstep between [kí] and [chí], these must be associated to two different H tones, one spread from /ní/ onto /ki/ and one underlying on /chí/. Since the OCP violation is not fixed up by deletion (35a), fusion (35c), or by the blocking of spreading (35b), the OCP must be ranked below all the constraints discussed earlier. We see then that like any other constraint in OT, the OCP is violable if it is outranked by other conflicting constraints.

- (35) *Kishambaa: Survival of H tone sequences: MAX-T, SPECIFY-T, NO-FUSION » OCP*

| /niki-[chikoma]/ H ₁ H ₂ | MAX-T | SPECIFY-T | NOFUSION | OCP |
|---|-------|-----------|----------|-----|
| (a) niki-[chikoma] H ₁ | *! | * * * | | |
| (b) niki-[chikoma] H ₁ H ₂ | | *! | | |
| (c) niki-[chikoma] H _{1,2} | | | *! | |
| (d) niki-[chikoma] H ₁ H ₂ | | | | * |

The case-studies in this section have offered a fairly typical cross-section of the mechanisms needed for tonal phonology in OT, including positional markedness (ALIGN-R(Contour), *HEAD/L) and positional faithfulness (HEAD-MAX-T). These are mechanisms often motivated first in the segmental domain, yet clearly applicable to tonal phonology also, underlining the observation that although tone may seem exotic to an English speaker, it is nonetheless governed by the same mental machinery as vowels, consonants, and stress systems.

10.4 Tone and its surroundings

This brief chapter does not have room to explore the full range of issues related to tonal phonology. For more details see Yip (2002). The following brief remarks are included to emphasize that the full picture is far more complex than the fragments that have been dealt with above.

10.4.1 *The interfaces between tone and intonation*

This chapter concerns lexical tone, but even languages that lack lexical tone typically use the pitch of the voice to convey sentence level meanings, or intonation. It appears that both uses of tone use the same primitives, and can interact with each other. They also share certain other properties, in particular an attraction to head positions. (See Gussenhoven [ch.11]). Languages may use tone for both purposes, although lexical tone languages sometimes use other mechanisms instead of pitch for sentence-level meanings, for example sentence-final particles. Sentence-level perturbations may increase the pitch range, or raise or lower the whole pitch range, or add boundary tones. For further discussion see Gussenhoven (2004), Ladd (1997), Xu (in press).

10.4.2 *Phonetics of tone*

A full understanding of tone needs an understanding of how it converts into a precise phonetic implementation. A central question is whether every syllable has a specification for tone at the end of the phonology, or whether some are unspecified, and acquire their surface pitch by interpolation from surrounding tonally-specified syllables, which serve as targets. Although languages like Mandarin Chinese (Chen and Xu 2004), in which perhaps all syllables have lexical tones, do exist, a considerable body of evidence shows that in many languages only H are targets (Shona: Myers 1999), or that even if both H and L are targets (as in Navajo: deJong and McDonough (1993) and McDonough (1999)) many syllables are unspecified for either (Pierrehumbert and Beckman 1988 on Japanese).

A second unresolved issue is the location, if any, of the phonetics/phonology boundary. Many tonal changes have clear roots in phonetics. Two phenomena - declination and peak delay - are of interest here because they have been phonologized in many languages. The phonologization of declination is extremely widespread, especially in Africa, where it has given rise to a phonological process called downdrift by which high tones are drastically lowered after low tones. Turning to peak delay, in Yoruba (Akinlabi and Liberman 2000), peak delay has developed into a phonological process that turns a high-low sequence into a high-falling sequence by spreading the high tone.

(36) rárà (H.L) → rárá (H.HL) ‘elegy’

More generally, tone spread or shift to the right is very common, but tone shift or spread to the left is much rarer.

I end this section with a rather obvious point. Just like segmental contrasts, tonal contrasts can be affected by co-articulation effects (Peng 1997, Xu 1994). The laryngeal articulators have their own inertia, and it takes time for change to take place. Hearers seem well able to compensate for these effects, and continue to recognize the tones, but nonetheless caution must be observed in deciding whether some particular tonal effect is phonetic or phonological, and the answer is not always clear (Kuo, Xu, and Yip to appear).

10.4.3 Acquisition of tone

Very little is known about the acquisition of tonal phonology. We do know that infants mimic the pitch contours of the ambient language very early, and this applies to lexical tone as well as intonation, so the inventory of contrastive tones is acquired early. Children successfully master lexical tonal contrasts by around their third year, earlier if the language does not have too many alternations. They produce the tones quite accurately at a stage when some adult-like segmental production is still eluding them. See Li and Thompson (1977), Tse (1978), Demuth (1992, 1993, 1995), So and Dodd (1995). However, we know much less about the acquisition of the phonology proper, including alternations. Li and Thompson's work finds that the third-tone sandhi rule is not fully reliable at age three, when their study stops, but Demuth's work on Sesotho finds good control of some but not all rules by age three. (See Fikkert [ch.23], for some remarks, and also the summary in Yip 2002: ch.10).

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