NONMETRICAL CONSTRAINTS ON STRESS

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Abstract

Metrical theory emphasizes rhythmic aspects of stress and treats primary stress as secondary stress plus something extra. This work argues that primary stress in many languages is not governed by rhythm, but is assigned by autonomous principles. An alternative view of primary stress is proposed in which syllables compete for prominence. A small set of constraints account for a wide variety of basic stress patterns and predict the existence of other patterns which are as yet unattested. In detailed analyses of several languages, the new constraints yield insightful accounts of lexically-idsyncratic stress patterns and of the relationship between stress and morphological structure. The fundamental claims of the model are: (1) primary stress identifies the winner of a competition for prominence; (2) stress systems vary along a continuum defined by the degree to which stress at one edge of a word is favored over stress at the other; (3) stress is affected by the proximity of vowels to the edges of morphological domains; (4) lexically-idsyncratic stress patterns reflect gradient underlying prominence associated with particular vowels in the lexicon; and (5) the lexicon contains gradient phonological features which function as weighted constraints on surface representations.
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Chapter 1:

The central tenet of metrical theory is that utterances are organized into rhythmic constituents, and the prominence of stressed syllables is a reflection of that constituent structure. In other words, metrical theory emphasizes the role of rhythm in determining the location of stress. The present work argues that this view of the relationship between rhythm and stress is inadequate, particularly in respect to primary stress. Although secondary stresses typically reflect simple rhythmic patterns, primary stress in many languages is not subordinate to the same principles underlying rhythmic secondary stresses. Since primary stress is not necessarily dependent on secondary stress, it’s important to ask what other principles govern the assignment of primary stress. Despite overwhelming evidence that primary stress at least can be assigned independently of rhythmic secondary stresses, comparatively little effort has been focused on the principles governing the assignment of primary stress, per se. Unfortunately, if the only tool you have is a metrical hammer, everything looks like rhythm. In the absence of an adequate understanding of primary stress, the theoretical mechanisms underlying rhythmic secondary stresses are often employed inappropriately to account for nonrhythmic primary stress.

The present work begins by setting aside rhythmic or metrical prominence to focus on primary stress as an autonomous process. Primary stress will be analyzed in terms of the basic principles outlined in (1). These principles make no reference to rhythm, and are in this sense nonmetrical. These principles will subsume many cases of primary stress which have previously been described with reference to rhythmic devices.

1. Culminativity—syllables compete for prominence
   Directionality—the competition depends in part on the linear order of syllables
   Syllable Weight—prominent syllables attract stress
   Position—stress may be favored or disfavored near certain morphosyntactic edges
   Lexical Stress—lexical entries may have explicitly stressed or unstressed vowels

The proposal I make is that primary stress assignment can be analyzed in terms of constraints on the eligibility of vowels to bear stress, combined with competition between syllables for prominence. The effects of linear order, syllable prominence, morphosyntactic structure, and the lexicon will be embodied in constraints reflecting the basic principles of (1) above. The fundamental claims of the Nonmetrical Constraints model of stress (henceforth NMC) are:

1. Primary stress identifies the winner of a competition between syllables for prominence
2. Stress systems vary along a directional continuum defined by the degree to which stress earlier in a word is favored over stress later in a word
3. Stress is sensitive to the edges of morphological constituents, and may be either attracted towards or repelled away from particular edges on a language-specific basis
4. Lexically idiosyncratic stress patterns involve underlying prominence associated with particular vowels in the lexicon; underlying prominence is a phonological feature reflecting otherwise-unpredictable surface prominence

The NMC model integrates lexical stress into an overall framework for stress instead of treating words with idiosyncratic stress as deviant exceptions requiring
separate rules or special processing. The following assumed properties of phonological information in the lexicon make this possible:

1. Underlying phonological representations in the lexicon are gradient — feature values vary along a continuum
2. Underlying phonological features are constraints on surface representations, and the value of each feature in a lexical entry specifies the strength of the constraint imposed by that feature on the surface representation
3. Underlying lexical representations are as simple as possible; underlying features are only as strong as they must be to reproduce correct surface forms

Before beginning in earnest, it may be helpful to explicitly note some of the assumptions underlying the discussion in the following chapters. I will be discussing primary stress from a generative linguistics point of view. The goal will be to develop a theory of (partial) grammars for producing the patterns of primary stress possible in human language. I will focus on the representations and processes required to produce stress on the appropriate syllable, given an underlying phonological and morphological representation. This is a conventional linguistic approach, but it’s unrealistically simple. The relationship between stress and syllable structure, for example, is bidirectional — in general, each can influence or constrain the other (though most languages exhibit influence primarily in one direction or the other). More importantly, the knowledge speakers have of their own language allows them to use language both productively and receptively; they can understand as well as produce language. If morphological or phonological structure determines the location of stress, the location of stress can also be used as a cue to morphological or phonological structure. In other words, constraints go both ways. I will discuss mappings from phonological and morphological structure to stress, and ignore the inverse relationship. A more complete account would involve reciprocal constraints in both directions.

There are two fundamental ways to determine which syllable in a word will receive the primary stress. The traditional approach is to describe a set of rules or constraints which impose structure on the phonological form associated with a word. This approach is similar in spirit to the idea that a central pattern generator coordinates the neural activity responsible for controlling all the muscles involved in walking (cf. Thelen & Smith, 1994). The underlying assumption is that the essence of the task is embodied in some abstract central repository of knowledge and control. The problem with this perspective, whether applied to language or to motor control, is that it doesn’t deal very gracefully with dynamic adaptability, flexibility, and exceptions to the normal patterns. As Thelen & Smith (p. 9) put it, “walking is not controlled by an abstraction, but in a continual dialogue with the periphery”. The same can be said about speech. An alternative approach is to view stress as an emergent property of interactions between syllables competing for prominence. This is the view underlying the model of primary stress proposed below. From this perspective, there is no central pattern generator governing the assignment of stress. Each syllable brings certain resources to the task, and the location of stress emerges from competitive interactions between syllables.

I assume here that stress is assigned dynamically each time a word is used rather than simply being listed in the lexicon. I’m concerned with the (mostly implicit) knowledge speakers have about the stress patterns of their language—knowledge that they can employ productively. For this purpose, it matters very little whether any particular word came out of the lexicon or was the product of a productive word creation process. Following standard practice, I will categorize languages in terms of their basic productive stress pattern without implying that all words in the language exhibit that pattern. Spanish, for example, will be considered an example of a language with penultimate stress, even though a number of words
idiosyncratically exhibit antepenultimate or final stress. Any adequate theory of stress must be able to deal with such lexical exceptions as well as the rules. In analyzing lexical stress within the NMC model (see Chapter 3), I maintain that the lexicon contains just enough information about stress to reproduce the correct pattern (that observed by a language learner).

I also assume the input to the stress assignment process is a presyllabified word, and that the entire word is available simultaneously. This is consistent with other generative theories of stress and phonology in general. I follow the convention of representing time from left to right, and I use directional terms like leftmost and rightmost interchangeably with temporal designations like beginning and end.¹

The theory of stress I develop is a model of stress assignment at a fairly high level of abstraction. It abstracts away from the details of articulation or perception, and focuses on a low-dimensional, principles and parameters description of the relevant linguistic knowledge (arguments for a principles-and-parameters approach to language can be found in Chomsky, 1986, especially pp. 145 and following). The overriding principle of primary stress assignment is that vowels compete for primary stress. Additional principles govern the capacity of a vowel to compete for stress based on its proximity to certain morphological edges, the structure of the syllable containing it, and any underlying prominence assigned to it in the lexicon. These principles are instantiated as constraints on stress assignment, and the relative importance of each constraint is determined by a numeric parameter specifying the weight of that constraint.

The remainder of this chapter sets the stage for the NMC theory of primary stress by reviewing the dimensions of linguistic structure which influence stress and the relationship between stress and rhythm. A brief review of current stress theory is also presented, and the last section of this chapter develops a notation for coding patterns of primary stress. Chapter 2 introduces the basic constraints on nonmetrical stress, concentrating on the relationship between morphological edges and stress. Chapter 3 illustrates those constraints by examining several stress systems in some detail, and highlights the role of underlying prominence in accounting for lexically-governed stress patterns. Chapter 4 expands the coverage of the theory to a much broader range of stress systems by introducing directional prejudice and competition between syllables for stress. Chapter 5 reintroduces rhythmic constraints on stress and places the NMC model within a broader theoretical framework (Optimality Theory). Chapter 6 summarizes the principles and parameters of primary stress assignment developed in the earlier chapters, and discusses some implications of the NMC model for stress theory and for phonological theory in general. Much of the formal analysis of the NMC model developed in Chapters 2–4 is relegated to Appendices A–C, and Appendix D provides indexes of primary stress systems, one organized by language and one organized by stress pattern.

1.1. Kinds of Stress

Linguistic theories of stress at least since Liberman (1975) have emphasized the relationship between stress and rhythm. Primary stress is assumed to be a special case of rhythmic stress and not an independent phonological construct. As Goldsmith (1990:170) puts it, “the most important characteristics determining stress patterns are rhythm (i.e. alternating prominence) and sensitivity to inherent syllable (or rhyme) weight”. While these are clearly important factors, especially in determining secondary stress, the relationship between stress and rhythm is complicated by the fact that stress is often a cue not only for rhythmic organization, per se, but also for other dimensions of linguistic structure. These include syllable structure, morphological and syntactic structure, the identity of individual lexical items, and the

¹Thanks to Anne Loring for reminding me that speech doesn’t really go from left to right.
linear order of syllables within a word. These facets of stress are reviewed briefly below.

**Rhythm**

Rhythmic stresses typically target alternating syllables. Polish, for example, exhibits rhythmic secondary stress on odd-numbered syllables counting from the beginning of a word (Rubach & Boojj, 1985). Spanish has secondary stress on every other syllable before the primary stress, as exemplified in *constantinopolizac[y]ón* ‘constantinopolisation’ and *conde[n]spolizac[y]ionismo* ‘constantinopolisationism’ (Roca, 1986:253). Here and throughout, primary stress is marked with ‘ and secondary stress is marked with ’ where relevant. In some languages, every third syllable is stressed. Cayuvava, for example, places stress on every third syllable, counting from the end of a word, as in *me.dà.ru.e.e.ì.ro.hì.i.ae* ‘fifteen each (second digit)’ (Key, 1961, cited in Hayes, 1995:309). Syllable boundaries here and elsewhere are marked with a period.

Rhythmic stresses may be sensitive to the distinction between short (monomoraic) and long (bimoraic) syllables, at least in some versions of stress theory. In Lenakel, for example, stress in nouns falls on even-numbered syllables counting from the end of a word (Lynch, 1974, cited in Hayes, 1995:167). If there is a syllable with a long vowel, it is stressed (whether in an odd- or even-numbered syllable) and the odd/even count resumes from the syllable to the left of the long syllable. There is some debate about whether basic principles of linguistic rhythm should account for stress patterns like that of Lenakel, or whether these should be analyzed as a combination of prominential stress (placing stress on long syllables) and rhythmic stress (placing stress on alternating syllables in sequences of light syllables). Hayes adopts the former approach; Halle & Vergnaud (1987), for example, adopt the latter approach.

**Syllable prominence and stress**

Some languages exhibit stress on all relatively prominent syllables within a word, where relative prominence is determined by syllable structure, tone, vowel quality, or some other syllable characteristic. Koya, for example, places stress on all long or closed syllables, in addition to stressing the first syllable (Tyler, 1969, cited in Halle & Vergnaud, 1987:12). This kind of prominential stress is an example of the rich get richer principle—syllables which are already prominent in some way are stressed. A syllable might intrinsically be perceptually salient because of a long vowel, a high tone, a low vowel, a voiceless onset, etc. It is generally assumed that “any given factor influences prominence in only one direction” (Hayes, 1995). We therefore do not expect to find languages in which short syllables are treated as relatively prominent, for example. As Martin (1972:489) noted, “speaking and listening are dynamically coupled rhythmic activities.” Prominential stresses may facilitate perception by reinforcing reference points a listener can lock onto (cf. Martin, p. 504; Pitt & Samuel, 1990:564).

**Morphosyntactic constituent structure**

In many languages stress serves as a cue for the morphological structure of words. The stress pattern of Koya mentioned above places stress on the initial syllable of each word in addition to the prominence-based stresses on long and closed syllables. The initial stress of Koya clearly identifies an important constituent boundary—the beginning of a word. A single stress can signal the likely proximity of several edges at the same time. In Spanish, stress normally falls on the last syllable of a noun stem. Word-final stress is seen in words composed of just a stem, like *doctór* ‘doctor (masculine)’, but penultimate stress is observed when the stem is followed by an inflectional affix, as in the feminine form *doctóra* or the plural form *doctóres*. The stress in Spanish clearly signals the end of a noun stem. In addition, since the stressed
syllable is never more than one or two syllables from the end of a word, it serves as a somewhat imprecise, coarse-grained cue for the end of a word.

In Classical Latin, stress falls on the penultimate syllable if it is long or closed, otherwise on the antepenultimate syllable. Here again, stress signals an upcoming word boundary in an approximate, coarse-grained way. The stress in Latin is also a redundant cue for syllable structure, since it tends to fall on long or closed syllables rather than short open syllables. The relationship between stress and morphological structure in Spanish and Latin is discussed in some detail in Chapter 3.

In addition to reflecting the internal morphological structure of a word, stress may also reflect the syntactic structure in which a word is embedded. Liberman & Sproat (1992), for example, argue that stress reflects the structure of modified noun phrases in English. According to their analysis, nominal collocations with phrasal stress on the left (e.g. folk tale, yellow pages, hardhat, square knot) form low-level compound noun (N0) constituents. Superficially similar word pairs with stress on the right (e.g. steel plate, spring flowers, blue moon, black death) are joined at a higher syntactic level to form N1 constituents. Since the two constituent structures are typically associated with different semantic interpretations, stress provides an important cue for interpreting modified noun phrases. The relationship between stress and syntactic structures will not be addressed in the present work. I will, however, pay some attention to the relationship between stress and morphological structure, with the expectation that the mechanisms required to account for those data will ultimately be involved in interactions between stress and higher level syntactic structures as well.

Lexical identity

Many or most stress languages have at least some words in which the location of stress is an idiosyncratic property of particular lexical items (stems or affixes). Lexical stress typically deviates only slightly from the location of stress which would otherwise be expected—stress shows up one syllable farther to the left or right. In Spanish, for example, primary stress is usually on the last syllable of a noun stem, as in doctor and related forms cited above. Stress idiosyncratically occurs on the second-to-last syllable of noun stems in words like canibal ‘cannibal’ and teléfono ‘telephone’. Similarly, in Polish, primary stress normally falls on the penultimate syllable, but idiosyncratic antepenultimate stress occurs in forms like uniwersytet ‘university’. Final stress occurs idiosyncratically in words like reżim ‘regime’. See Chapter 3 for detailed discussion and analysis of lexical stress in Spanish and Polish.

Lexical stress in Spanish words like teléfono-o and canibal somewhat attenuates the correspondence between stress and the end of the noun stem. This represents an apparently undesirable (i.e. maladaptive) reduction in the validity or precision of stress as a cue for morphological structure. However, the reduced validity in one dimension is offset by contrastiveness—stress helps determine the identity of lexical items in addition to the role it plays in signaling structure.
In Spanish and Polish, it’s the location of primary stress which is sometimes conditioned by individual lexical items. In those languages secondary stress is fully predictable, given the location of primary stress in a word. This is not the case for all languages, however. Lexical secondary stress is also attested, though it appears to be less common than lexical primary stress. English has a number of nouns with arguably idiosyncratic secondary stress on the final syllable, including *sycophant*, *romance*, *Jackendoff*, and *caravan* (cf. *elephant*, *resistance*, *BeetleBub*, and *garrison*, with unstressed final syllables; these examples follow Goldsmith, 1990:210, who credits Ross, 1972).  

Another example of idiosyncratic secondary stress is seen in Tübatulabal. In this language, primary stress falls on the final syllable of a word (Hayes, 1995:265). Secondary stress ordinarily falls on all syllables with long vowels, and on alternating syllables in sequences of short syllables (Prince, 1983, who cites Voegelin, 1935). Certain morphemes idiosyncratically condition stress on particular syllables. Prince cites *ti kapi* *ganayin* ‘the one who was eating’, where the lexically-stressed vowel of /pi ganá/ ‘recent past agentive’ surfaces with stress in a light penultimate syllable. The stress rules of Tübatulabal would not ordinarily place stress in this position. Prince also notes that the word Tübatulabal itself contains not one, but two lexical stresses. The underlying representation must be something like /tbi bátulabál/, with lexical stress on the second and fifth vowels. Thus, *ti bátulabal* by itself has stress on syllables 2 and 5, rather than the expected *ti batulabal* with stresses on 1, 3 and 5. The related word *ti bátulabalá:p* ‘Tübatulabal Indians’ has stress on syllables 2, 5 and 6, whereas the stress rules would predict the form *ti bátulabalá:p*, with stress on syllables 2, 4 and 6.

**Culminativity and linear order**

All stressed syllables are not created equal. As Larry Hyman put it, “the basic principle in a stress language is that only one syllable per word will receive primary stress” (Hyman, 1977:38). Primary stress represents the culminative aspect of stress, whereby a single syllable of a word is designated as the peak or head of the word. English words like *Mississippi* and *húmanešiténa* have several stressed syllables. One of these, the primary stress, is perceived as more prominent than the other stressed syllables. It is also the syllable with primary stress which serves as an anchor for intonational contours (Liberman, 1975).

Primary stress typically reflects some combination of syllable prominence, morphosyntactic constituent structure, lexical identity, and rhythm. This was evident in a number of examples discussed above. Linear order is another aspect of phonological structure which is relevant to primary stress. In Tibetan, for example, primary stress falls on the first syllable with a long vowel, no matter how far it is from the beginning of a word; if there are no long vowels in a word, stress falls on the first syllable (Hayes, 1995:297). In Huasteco, stress falls on the last syllable with a long vowel, or on the first syllable if there are no long vowels in a word (Larsen & Pike, 1949, cited in Hyman, 1977:51). Since primary stress in these languages can be arbitrarily far from the beginning or end of a word, it is not a reliable cue for constituent structure. However, it is a reliable cue for signaling the first or last prominent syllable in a word.

### 1.2. Rhythm and Metrical Feet

In order to appreciate the importance of nonmetrical (i.e. nonrhythmic) constraints on stress, it is essential to understand the role of rhythm in speech, as well as the relationship between feet, secondary stress, and primary stress. Stress makes
certain syllables more prominent than others. Acoustically, stressed syllables are often louder, longer, or have higher pitch than unstressed syllables. However, stress is often perceived even when these acoustic cues are absent from the speech signal (cf. Martin, 1972 and references therein). Noting that there are no simple correspondences between the acoustic characteristics of a syllable and relative stress or accent, Martin (p. 496) argues that stress is “a perceptual consequence of relative timing.” In other words, stress is a reflection of the rhythmic structure which determines the relative timing between elements of speech (also cf. Lenneberg, 1967; Martin, 1972; Neisser, 1967; Robinson, 1977).

Linguistic rhythm

Linguistic rhythm functions as a “carrier pulse” onto which phonetic information is modulated (Lenneberg, 1967:108). More or less periodic, repeating rhythms are observed in speech in the rising and falling sonority of syllable structure, and, in many languages, in alternations in prominence from one syllable to the next. English words like Mississippí and hāmanélidānthemum, for example, exhibit stress on alternating syllables. Regular patterns of stress facilitate perception and draw attention to particular syllables within a word. Pitt & Samuel (1990:564) suggest that “the temporal regularity from one stressed syllable to the next may provide a stable structure that the processing system can capitalize on by predicting the future occurrence of perceptually clear segments of speech (i.e. stressed syllables).”

Linguistic rhythm also provides references points for organizing auditory memory (Frings, 1914, cited in Robinson, 1977; Neisser, 1967:233). Cutler (1986) reviews a range of experimental research bearing on how stress patterns affect processing in speech recognition and production tasks. Stress pattern is relevant in substitution errors in production (e.g. in malapropisms and in the tip-of-the-tongue phenomenon), and it also affects performance in recognition tasks like those of Robinson (1977). In spontaneous errors as well as experimental settings, “errors of confounding are more likely to result from syllables exchanged between words that are rhythmically similar” (Robinson, p. 87). These data suggest that stress is an important factor in determining similarity between words stored in memory.

Subjective rhythm and metrical feet

Bell (1977) provides an introduction to the perception of rhythm and how it relates to the phonetic correlates of stress. One striking aspect of perception is subjective rhythm: a perfectly regular series of identical sounds (whether the sounds are tones, clicks, hisses, etc.) will be perceived as a sequence of groups of sounds, provided that the rate of repetition falls between about 0.5 to 5 times per second. For comparison, English speakers produce between about 4 to 8 syllables per second. The slower rates of speech lie at the upper end of the range for perception of subjective rhythm. The fastest speaking rates are generally restricted to relatively short utterances, especially common phrases or clichés (Lenneberg, 1967:90).

When a sound sequence consists of two sounds differing along a single sensory dimension (e.g. loudness, pitch, or length), the perceived groupings are organized around transitions from one sound to the other. Patterns with a single prominent element (loud, long, or high or low pitch) in each repeating group are easier to remember and reproduce than patterns involving a complex mixture of elements within each group. A sequence of loud and soft sounds occurring at equal intervals, say …SLSLSLLSLSL…, tends to be perceived in groups beginning with the loud sound, …LSS-LSS-LSS-… In contrast, a sequence of short and long sounds tends to be chunked into groups ending with a long sound, …SSL-SSL-… (providing the long sound is more than about 1.5 times the length of the short sound). A repeating pattern of relatively high and low tones may be perceived either as a succession of groups each beginning with a high tone, …HLL-HLL-…, or a succession of groups each beginning with a low tone, …LHH-LHH-….
Subjective rhythm demonstrates a predisposition to chunk temporal sound patterns. In linguistic theory, the basic unit or chunk of rhythm above the syllable is the metrical foot. A foot is a phonological constituent representing a prominence relation between the syllables within it—the head of the foot is relatively prominent or stressed, and nonhead syllables are relatively nonprominent, or unstressed. A word is parsed into feet to distinguish stressed from unstressed syllables. The feet are then gathered into a word tree. The head of one of the feet will be the head of the word and bear primary stress. These metrical structures are commonly represented on a bracketed metrical grid like that shown in (2). The grid represents time on the horizontal dimension, and degrees of prominence on the vertical dimension. Parentheses show the boundaries of constituents. The syllable with the highest column of asterisks is the most prominent—the primary stress. The dots shown on the grid are place holders, and are not part of the actual phonological representation.

\[
\begin{align*}
\text{Line 0: Syllables} & \quad * \quad * \quad * \\
\text{Line 1: Stress} & \quad * \quad \text{(*)} \quad * \\
\text{Line 2: Primary stress} & \quad . \quad . \quad . \\
\text{Mississippi}
\end{align*}
\]

metrical feet come in several shapes, with each language generally preferring one shape over the others. The theory of Hayes (1995) limits metrical feet to three types. The syllabic trochee, \( \sigma_\alpha \sigma \), is a left-headed constituent with two syllables; the internal structure of the syllables does not matter. The moraic trochee, \( \text{(*) or *} \), is a left-headed constituent consisting of two moras. A moraic trochee can contain either two light (monomoraic) syllables, or a single heavy (bimoraic) syllable. The third type of foot in Hayes’ theory is the iamb: \( \text{(*) if possible, otherwise }] \times \text{(*)} \text{. An iamb is a right-headed constituent with either two moras or two syllables.}

Hayes (1995:41-48) and Kenstowicz (1993) both review evidence for the role of metrical feet as important constituent structures in phonology. I will not review those arguments here. Reduplication and similar morphological “circumscription” processes may also employ feet or foot templates. In short, speech can be, and often is, chunked into small groups of syllables corresponding to something like metrical feet.

In some languages, stress appears to be assigned starting at the bottom of the metrical grid and working towards the top. After stressed syllables are identified on line 1 of the grid, one of them is selected as the bearer of primary stress, receiving a mark on the next higher line of the metrical grid. In many other languages, primary stress logically precedes the establishment of rhythmic stress. In these languages, stress appears to be assigned in a top-down fashion.

metrical theories of stress primarily assume that stress is a side-effect of parsing a word into metrical constituent structures. These theories—including those that do not rely on feet to assign rhythmic stress (e.g. Larson, 1992; Prince, 1983; Wheeler & Touretzky, 1991)—typically treat primary stress as a secondary phenomenon. As Prince put it, “the first duty of a stress system is to distinguish the stressed from the stressless” (Prince, 1983:47). In other words, stress is assigned from the bottom up.

Bottom-up assignment of stress is consistent with the naive intuition that primary and secondary stress differ quantitatively, with primary stress being more of something than secondary stress. This intuition is represented explicitly on metrical

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4 Sometimes feet are organized into binary constituents at an intermediate “colon” layer (cf. [Hayes, 1995 #122:119]). The “cola” are then gathered into a phonological word.

5 It should be noted that morphological processes involving feet don’t necessarily respect the phonological foot boundaries of the base form (McCarthy & Prince, 1990, fn. 9, p. 68).
grids, where stress is represented by the degree of prominence assigned to each
syllable, and the syllable with the highest prominence bears the primary stress. It’s
important to bear in mind, however, that relatively higher and lower levels of stress
are not reliably associated with more and less of some acoustic feature (cf. Hayes,
1995, chapter 2, and references therein). With respect to English, for example, Hayes
reviews diagnostics supporting the distinction between at least four levels of stress in
colloctions like totalitarian tendencies. Reliable diagnostics include
vowel quality, docking sites for intonational contours, and segmental rules which are
sensitive to stress. None of these diagnostics is quantitative. Loudness, pitch and
length, which can be measured quantitatively, are notoriously unreliable as direct
reflections of stress levels. Differences between primary and secondary stress
discussed below further demonstrate that primary and secondary stresses are different
things—primary stress is not just a glorified secondary stress.

**Bottom-up stress**

In a number of languages the location of primary stress depends on whether a
word (or a relevant portion of a word) has an odd or even number of syllables. For
example, in Munsee, stress in words with all light syllables (excluding the final
syllable) falls on the penultimate or antepenultimate syllable, whichever is an even
number of syllables from the beginning of the word (Hayes, 1995:212). Following
the analysis in Hayes, the stress pattern of Munsee is readily accounted for by parsing
the word into right-headed bisyllabic feet, starting at the left edge of the word, as
illustrated in (3). Primary stress is assigned to the head of the penultimate foot. In
Hayes’ analysis, the final foot is extrametrical, as indicated by the angle brackets in
(3), and the End Rule assigns stress to the rightmost available foot head. Subsequent
phonological processes account for the differences between the metrical
representation and the surface phonetic form of (3a).

(3)  a. [nu:lamâlsi] ‘I am well’   b. [wəlamalə sew] ‘he is well’

\[
\begin{align*}
\text{Primary stress} & \\
\text{Stress} & \\
\text{Syllables} & \end{align*}
\]

In Wargamay, primary stress falls on the initial syllable if heavy, otherwise on
the first or second syllable, whichever is an even number of syllables from the end of
alternating syllables following the primary stress. This pattern can be accounted for
by parsing the entire word into left-headed bimoraic feet, working from right to left.
The leftmost stressed syllable is then designated as the primary stress. The
illustrations in (4) follow Hayes. A language-specific prohibition against degenerate,
monomoraic feet prevents the initial syllable of (4a) from comprising its own foot.


\[
\begin{align*}
\text{Primary stress} & \\
\text{Stress} & \\
\text{Syllables} & \end{align*}
\]

The point of these examples is that some mechanism is needed to determine
whether a word has an odd or even number of syllables, because the location of
primary stress depends on an odd/even parity count. One solution is to assign
rhythmic stresses first, possibly by parsing words into metrical feet, and then elevate
one of the stressed syllables to the status of primary stress.\(^6\)

---

\(^6\)In terms of constraints rather than rules, bottom-up stress patterns can be
described by imposing constraints on rhythm (favoring output forms with alternating
stresses) and possibly conflicting constraints on primary stress (favoring stress on the
leftmost or rightmost syllable, etc.). The constraints on rhythm dominate, so that
primary stress respects the rhythmic principles (see Chapter 5 for further discussion).
Top-down stress

Goldsmith (1990:343, fn. 14) notes that “in a good number of languages, primary or word-level stress is assigned first, and secondary stress is assigned on the basis of the position of the word-level stress that is already assigned.” I review here some of the evidence that primary stress does not necessarily depend on the same factors which govern secondary stresses in a language. This evidence includes differences between primary and secondary stress with respect to syllable structure, right-left versus left-right directionality, and avoidance of word edges.

In many languages the location of stress depends on the internal structure of the syllables in a word. These languages are said to have quantity-sensitive stress. Heavy syllables, which attract stress, are distinguished from light syllables, which do not. The specifics of which types of syllables are heavy and which are light vary from language to language, but generally syllables with long vowels are heavy, and open syllables with short vowels are light. Closed syllables can be either heavy or light, depending on the language. A number of languages with both primary and secondary stress exhibit quantity-sensitive primary stress, but quantity-insensitive secondary stress. These include Romanian (Chitoran, 1995) and Spanish (Harris, 1992; Roca, 1986), for example. Such languages are sometimes described as restricting quantity-sensitivity to a small window near one edge of the word, so that it only affects the stressed syllable closest to the edge, i.e. the primary stress. Delattre (1966), for example, suggests quantity-sensitivity is active only near word edges in English. On the other hand, there are also languages which establish quantity-sensitive secondary stresses, and quantity-insensitive primary stress. Koya, for example, places primary stress on the first syllable regardless of syllable weight, and has secondary stress on all heavy syllables (Halle & Vergnaud, 1987:12). The relevant generalization is not that quantity-sensitivity or quantity-insensitivity can be restricted to a few syllables at one edge of the stress domain. The significant thing is that primary stress can be established independently of secondary stress.

In many languages primary and secondary stress are calculated from opposite edges of the word. In Polish, for example, primary stress falls on the penultimate vowel, while secondary stress falls on odd-numbered syllables starting at the beginning of the word (Rubach & Booj, 1985). Piro exhibits essentially the same pattern of primary and secondary stresses (Hayes, 1995:201). Other languages which assign primary stress relative to the right edge and secondary stress relative to the left edge include Romanian (Chitoran, 1995), as well as German, Lenakel, Modern Greek, and Onondaga (Hayes, 1995). Hayes also discusses languages in which primary stress is calculated relative to the left edge of a word, while rhythmic secondary stresses are laid down starting at the right. These include Czech, Garawa, and Gugu-Yalanji. Again, the evidence points to the independence of primary stress from secondary stress.

Even when primary and secondary stress are calculated from the same edge, there may be different constraints on primary and secondary stress in addition to the quantity-sensitivity/insensitivity distinction discussed above. One common example involves languages which place primary stress on the rightmost nonfinal stressed syllable. In English, for example, the last stressed syllable of *hànuméladànthemun* bears the primary stress. In contrast, primary stress is on the second-to-last stressed syllable in *rígamárólë*. As Hayes (1981) described it, “the main stress in English words falls on the last stressed syllable that isn’t in word final position.” The same generalization could be applied to Munsee, discussed above (cf. figure 3). Other languages in which the final syllable is evidently invisible to primary stress but not to metrical feet and secondary stress include Dutch (van der Hulst, 1984) and Classical Latin (Mester, 1994). In these languages, feet have no problem with the last syllable of a word, but primary stress avoids word-final syllables. Indonesian exhibits a

7Liberman & Prince ([, 1977 #56]) attribute this observation to an unpublished manuscript by S. Schane.
different difference between primary and secondary stresses. Cohn & McCarthy
(1994) describe stress in Indonesian and note that schwas are invisible to stress
assignment, but are not necessarily invisible to foot structure. In other words, there
are different principles at work on primary and secondary stress.

A number of other works have also suggested that stress may sometimes be
assigned in a top-down rather than a bottom-up fashion. Kager (1991, cited in Hayes,
1995:264) suggests an analysis of Tukbatulabal in which primary stress is assigned
first, followed by the construction of rhythmic constituents representing secondary
stress. Prince (1983:51) employs three different rules to distinguish stressed from
stressless syllables in Hawaiian, and then places primary stress on the rightmost
stressed syllable. He notes in passing that significant economy would be achieved by
directly assigning primary stress first, though he does not pursue that idea. Hayes
(1995:117) discusses top-down vs. bottom-up parsing, and lists a number of
languages in which primary stress is evidently assigned before secondary stress.
These include Swedish, Tiberian Hebrew, Cahuilla, Tümpisa Shoshone, Czech, Mayi,
Old English, Cayuvava, and Estonian. Hayes (1985:440) similarly identifies a
number of languages in which primary stress is either determined lexically or is
assigned before secondary stress, including Lenakel, Southwest Tanna, Modern
Greek, German, Bikol, Garawa, and Modern Hebrew. Primary stress is not just a
matter of adding something extra to a prior secondary stress.

Prominence-based stress

According to Hayes (1995), another distinction between primary stress and
rhythmic secondary stresses is that primary stress may be sensitive directly to various
aspects of syllable prominence, while metrical feet are sensitive only to moraic
quantity, i.e. the binary distinction between long and short syllables. Moraic quantity
is a property of the time dimension—a syllable can be heavy and attract stress by
virtue of its length. Because of its temporal aspect, moraic quantity is relevant for
rhythm, and can affect the construction of metrical feet. Prominence, on the other
hand, is identified with perceptual salience. A syllable might sound louder because of
its long vowel, its high tone, its low vowel, its voiceless onset, etc. In Hayes’ theory,
prominence is irrelevant to foot construction—feet refer only to moraic quantity.⁸

Some stress systems distinguish more than two degrees of syllable weight.
Hayes argues that the location of stress in these systems is governed directly by
prominence, and not by the rhythmic principles underlying metrical feet. In Pirahã,
for example, primary stress falls on the heaviest of the last three syllables (Everett &
Everett, 1984). In the event of a syllable weight tie, stress falls on the syllable which
is closer to the end of the word. Pirahã arranges syllable types in a hierarchy of
syllable weights such that KVV > GVV > VV > KV > GV, where K and G represent
voiceless and voiced consonants, respectively; V and VV represent short and long
vowels. Hayes computes the location of stress in Pirahã on a prominence plane,
distinct from the metrical grid on which syllables are organized into feet. As shown
in (5), the prominence plane has a column of marks representing the weight of each
syllable, with heavier syllables represented by higher columns. The prominence plane
is projected below the corresponding syllable string, and stress is marked on the
metrical grid above the syllable string. On the prominence grid, ‘.’ are place holders
showing the prominence of syllables which are not projected onto the prominence
grid because they are too far from the edge of the word. High tones have been omitted
from the transcriptions in (5). Hayes’ analysis restricts stress to the last three
syllables by stipulating that only the last three syllables project their prominence onto

⁸Hayes’ distinction between prominence-based stress and foot-based stress is
reminiscent of the distinction between prominence and rhythm made by Liberman &
Prince (1, 1977 #56) and Prince (1, 1983 #53).
the prominence plane. The End Rule then assigns stress to the rightmost syllable at
the highest level of prominence.

(5) a. [ʔa.ba:.pi] b. [ʔa.pa.haː.si] c. [poː.gai.hi.əi]  
(proper name)  'square' 'banana'

Hayes’ use of a prominence plane distinct from the metrical grid
acknowledges that the location of stress in Pirahã is determined by principles distinct
from those which establish metrical feet. In Pirahã and in other languages with more
than two levels of syllable weight, primary stress is governed by prominence, and not
by rhythm. The same is true of stress systems which depend on non-moraic
characteristics of a syllable, like presence or absence or voicing of an onset, or high
versus low tone. Languages which Hayes cites as examples of prominence-based
stress include Asheninca, Hindi, Serbo-Croatian, Lithuanian, and Golin.

1.4. Metrical Theories of Stress

The significance of top-down stress languages is that the location of primary
stress is not necessarily determined by the rhythmic principles which so often govern
secondary stress. However, it seems to be an unwritten rule of metrical theory that
bottom-up accounts are preferable, and stress is assigned in a top-down fashion only
as a last resort. Even when primary stress is given precedence over other rhythmic
secondary stresses, nearly all recent works in metrical theory employ metrical feet to
determine the location of primary stress. This is really a back door bottom-up
approach; it assumes that rhythm is THE fundamental determinant of stress. The bulk
of the present work explores nonrhythmic aspects of primary stress. To set the
theoretical context for this work, the next few sections review recent formalizations of
stress, all of which (over?)emphasize the rhythmic aspects of stress.

Rule-based metrical theory

Rule-based approaches to metrical theory constitute an enormous volume of
literature. The most influential works include Halle & Vergnaud (1987), Harris
(1983), and Selkirk (1980). Abstracting away from the details of any particular
theory, a stress pattern like that shown in (2), repeated here as (6), would be assigned
by a series of rules like those in (7). Rules apply one at a time in a structure-building
derivation, with the output of one rule serving as the input to the next. Since stress is
a property of syllables, and also since the location of stress is often sensitive to
syllable structure, segments must be organized into syllables before stress is assigned.

(6) {...} Line 2: Primary stress  
(* {...}) Line 1: Stress  
Mississippi Line 0: Syllables

(7) a. Represent each syllable with a mark on line 0 of the metrical grid
b. Group elements on line 0 into binary, left-headed constituents on line 1
c. Group elements on line 1 into a single right-headed constituent on line 2

In a rule-based theory of phonology, learning a language involves learning
appropriate underlying representations and either learning rules or appropriate
parameter settings for a set of universal rule templates. It may also be necessary to
learn the order in which rules must be applied.
Optimality Theory

Optimality Theory (OT) approaches to stress adopt the metrical grid representation, but eliminate rules in favor of constraints on output representations (McCarthy & Prince, 1993; Prince & Smolensky, 1993). Rather than specifying how the correct output form should be constructed step by step from an underlying representation, the constraints specify what a well-formed output should look like. All possible output forms are evaluated simultaneously against the constraints, and the form which satisfies the most high-ranking constraints is selected. As an example, suppose the constraints in (8) specify the ideal properties of a metrical representation:

(8)  a. FOOTBINARITY — each metrical foot should contain exactly two syllables  
    b. HEADLEFT — feet should be left-headed  
    c. RIGHTMOST — primary stress should be as far to the right as possible

The metrical representation in (6) can be conveniently re-represented as (Ml.ssi)(ssi,ppi). This form satisfies the FOOTBINARITY and HEADLEFT constraints. However, it does not completely satisfy the RIGHTMOST constraint, because stress is on the penultimate rather than the final syllable — stress is not quite as far to the right as it could conceivably be. This illustrates an important tenet of OT: constraints are violable. However, constraints are only violated if it is impossible to satisfy all constraints, and if the violation of a low-ranked constraint makes it possible to satisfy a higher-ranked constraint. Constraints are ranked in a hierarchy, all possible output forms are evaluated simultaneously against the constraints, and the output form which satisfies the most high-ranking constraints is selected. This constraint satisfaction process can be represented in a constraint tableau, as in (9).

<table>
<thead>
<tr>
<th>Candidates</th>
<th>FOOTBINARITY</th>
<th>HEADLEFT</th>
<th>RIGHTMOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (Ml.ssi.ssi,ppi)</td>
<td>*</td>
<td></td>
<td>* * *</td>
</tr>
<tr>
<td>b. (Ml.ssi)(ssi,ppi)</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>c. (Ml.ssi)(ssi,ppi)</td>
<td></td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

A constraint tableau lists the output candidates vertically, and the relevant constraints horizontally. Constraints are listed in rank order, with the highest-ranked constraint on the left. Each output candidate is evaluated against the constraints, and a ‘*’ is entered into the table for every violation of a particular constraint. A ‘!’ marks fatal violations, i.e. constraint violations which cause an output candidate to be rejected in favor of some other candidate which better satisfies the constraints.

Candidate (9a) violates FOOTBINARITY twice because it is parsed into a single four-syllable foot — this foot has two more syllables than allowed by the constraint. Candidate (9a) also violates RIGHTMOST three times because there are three syllables between the primary stress and the right edge of the word. Candidate (9b) satisfies FOOTBINARITY and RIGHTMOST, but violates HEADLEFT twice because it has two right-headed feet. Candidate (9c) satisfies FOOTBINARITY and HEADLEFT, but violates RIGHTMOST because there is a syllable between the primary stress and the right edge of the word. If the constraints of FOOTBINARITY, HEADLEFT, and RIGHTMOST are ranked in that order, as shown in (9), then candidate (9c) will be chosen as the most optimal candidate. Each of the other candidates is rejected because they violate higher-ranked constraints.

OT emphasizes the role of constraints on output representations. Constraints are assumed to be universal, and languages differ in the relative ranking of the constraints. Learning a language therefore involves learning appropriate underlying forms and appropriate constraint rankings.
Harmonic Phonology and the Dynamic Linear Model of stress

Harmonic Phonology (Goldsmith, 1993; Lakoff, 1993) proposes a hybrid system of rules and constraints on representations. The basic idea is that phonological generalizations can be described in terms of a small number of levels of representation (e.g. three) and constraints on the representations at each level. There are two types of rules: rules that relate representations on different levels, and rules for maximizing the satisfaction of constraints within each level. A phonological representation is maximally harmonic if it satisfies relevant constraints to the greatest extent possible. Harmonic Phonology differs from Optimality Theory in having language-specific rules specifying how constraint violations will be repaired (or avoided).

Within the framework of Harmonic Phonology, the Dynamic Linear Model of stress (DLM) is a model of the representations, rules, and constraints on stress within a particular phonological level (Goldsmith, 1991; 1992; 1993; Larson, 1992). The representation consists of a prominence value for each syllable, which is calculated through an iterative process so as to maximize the satisfaction of constraints on the prominence of each syllable. Something that sharply distinguishes the DLM from both rule-based and OT accounts of stress is that representations and constraints in the DLM are gradient: prominence can range over all numbers within a real interval (usually between −1 and 1); the relative importance of each constraint is likewise specified by a real-numbered weight value.

There are two types of constraints in the DLM: local constraints on the prominence of individual syllables, and interactive constraints on the relative prominence of each syllable in relation to its immediate left and right neighbors.

---

These constraints are schematized in (10). Each circle represents a syllable, and the arrows represent local and interactive constraints on the prominence of each syllable.

\[ \text{(syllable weight, positional bias)} \]

The two local constraints discussed by Goldsmith and Larson are syllable weight and positional bias. Syllable weight determines the extent to which stress is favored on heavy syllables compared to light syllables. Positional bias favors or disfavors stress on particular syllables based on their position relative to the beginning or end of the word. A language with penultimate stress, like Polish, would have a positive positional bias applied to the second-to-last syllable to function as a constraint in favor of stress on the penult (cf. Goldsmith, 1992).

The interactive constraints in the DLM establish a competition for prominence between adjacent syllables. Each syllable tries to suppress prominence in its neighbors, and the amount of influence a syllable has on its neighbors is directly proportional to its own prominence. A syllable which achieves a high level of prominence will suppress prominence in its neighbors, and the resulting prominence peak identifies the location of a stressed syllable. The competition for prominence is governed by two values which affect how much influence each syllable has on the syllable to its left and right, respectively. These values taken together establish a directional bias which determines whether stress will be established primarily from the left or right edge of a word. According to the DLM, learning a language

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Goldsmith and Larson generally referred to this model of stress as a Dynamic Computational Model. I adopt the more descriptive term Dynamic Linear Model, following Prince ([1993 #50]).

---

Prince ([1993 #50]) makes the directionality of the DLM more explicit by reformulating parameters of the model so as to obtain a left-right asymmetry parameter. A similar directionality parameter will be introduced into the NMC model in Chapter 4.
involves learning how strongly each syllable inhibits its left and right neighbors, and also involves learning appropriate positional biases.

Competition between syllables for stress distinguishes the DLM from rule-based and OT approaches to stress. Those approaches emphasize the construction of constituent structure over a passive string of syllables. Abstract knowledge of stress is concentrated in some centralized control process. The DLM views syllables as autonomous entities, actively competing for prominence. Stress is an emergent property of this competition.

Connectionist models of stress

As the schematization in (10) suggests, the DLM may be considered a connectionist model of stress. The gradience and interaction between autonomous units central to the DLM are typical characteristics of connectionist models (cf. Anderson, forthcoming or Rumelhart & McClelland, 1986, for example). Other connectionist models of stress include Gupta & Touretzky (1994) and Wheeler & Touretzky (1991).

Like the DLM, Wheeler & Touretzky sketch a computational model of syllable structure and stress based on Harmonic Phonology. The Wheeler & Touretzky model focuses on mappings between representational levels rather than the satisfaction of constraints within a level, which is the focus of the DLM. Unlike the DLM, the Wheeler & Touretzky model employs standard linguistic featural representations rather than gradient representations.

Gupta & Touretzky demonstrate a simple connectionist model that learns a variety of stress patterns. Their model is intended not so much as a serious account of stress, but as an illustration of the potential pitfalls of assuming that an abstract, high-level linguistic theory will provide insight into lower-level mechanisms involved in linguistic processing. Gupta & Touretzky make no attempt to account for interactions between morphological structure and stress, nor do they account for lexical stress.

They do point out that linguistic theories are often built on simplified data sets, and question the validity of the resulting approximate theories (p. 26).

1.5. Syllable Priority Codes

The discussion above emphasizes the distinction between primary stress and rhythmic secondary stress. Before proceeding to nonmetrical constraints on primary stress, it will be useful to adopt a notation for representing various patterns of primary stress. This notation will facilitate comparisons between stress systems, and provides a useful key for indexing languages according to stress system, as in appendix D.2.

Primary stress systems exhibit a wide range of patterns. Latvian, for example, places stress on the first syllable of a word. Hindi exhibits a considerably more complex pattern. In Hindi, stress falls on the rightmost superheavy syllable (excluding the final syllable), or on the final syllable if it’s superheavy and there are no other superheavies, otherwise on the rightmost heavy syllable (excluding the final syllable), or if all syllables to the left of the final are light, stress falls on the first syllable (Hayes, 1995:276). Prose descriptions of stress patterns as complex as that of Hindi are quite awkward, and I will adopt a more concise notation for describing patterns of primary stress. This system of Syllable Priority Codes will be a useful tool for categorizing, sorting, and comparing stress systems.

Most primary stress systems can be described by conditional statements of the general form, “Syllable A if heavy, else syllable B if heavy, ... else syllable Y if heavy, else syllable Z.” The stress pattern of Latvian is a degenerate case of the general form, reducing to just “Stress syllable 1.” Hopi provides a slightly more complex example: “Stress syllable 1 if heavy, else syllable 2.” Some stress systems have more than two levels of syllable weight, like the Hindi pattern described above. These can be described by generalizing the conditional statement to additional degrees of syllable weight, beginning with the heaviest and working down. In this format, the Hindi stress pattern would be reformulated as “Stress the penultimate
syllable if superheavy, else the antepenultimate syllable if superheavy, ..., else the 
first syllable if superheavy, else the final syllable if superheavy; else the penultimate 
syllable if heavy, else the antepenultimate syllable if heavy, ..., else the first syllable.“

Given this convention for describing stress systems, a Syllable Priority Code 
(SPC) describing a stress system can be constructed from the numerical indexes for 
the syllables referred to in the conditional statement describing the stress system. The 
SPC for the stress pattern of Latvian is just “1” (stress syllable 1), and the SPC for 
Hopi is “12” (stress syllable 1 if heavy, else syllable 2). In these examples, stress is 
assigned relative to the beginning of a word. In general, stress may be assigned 
relative to either the beginning or the end of a word, depending on the language. It’s 
often useful to discuss a particular stress pattern and its mirror image counterpart, 
abstracting away from leftward or rightward directionality. I will refer to the edge 
closest to the highest priority syllable (the syllable mentioned first in the conditional 
statement describing the stress pattern) as the “near edge”, and the opposite edge of a 
word will be the “far edge”. In constructing SPCs, syllables will be numbered 
starting at the near edge, so that “syllable 1” always refers to the syllable at the edge 
closest to the highest priority syllable, whether that’s the left or right edge of a word. 
Thus, the SPC “1” designates the first-syllable-stress pattern of Latvian, and also the 
mirror image final-syllable-stress pattern observed in Weri. Any stress pattern and its 
mirror image counterpart will be designated by the same SPC number. When it’s 
important to identify whether stress is figured from the left or the right, we can 
append an L or R to the SPC, e.g. “12L” for Hopi (stress the first syllable if heavy, 
else the second syllable) versus “12R” for the mirror image pattern observed in 
Ancient Greek (stress the final syllable if heavy, else the penultimate syllable).

The designation of unbounded stress systems like that of Hindi will require 
two further refinements of the SPC notation. Descriptions of the Hindi stress pattern 
refer to syllables near both ends of the word. The numbers 1–4 refer to the first four 
syllables at the edge closest to the highest priority syllable (the near edge). Since it’s 
rarely necessary to designate specific syllables more than 4 syllables from an edge, I 
will use the numbers 6–9 to refer to the last four syllables at the far edge. Syllable 9 
refers to the edgemost, farthest syllable, syllable 8 refers to the next-to-edgemost 
syllable, and so on. In using this notation, it’s important to keep in mind that 
“syllable numbers” stand for the concepts “farthest syllable”, etc., and are not tied to 
words of a particular length. In a language with final stress, for example, syllable 1 
refers to the final syllable of a word of any length, and syllable 9 refers to the first 
syllable. Although this may at times introduce some confusion, I think the SPC 
conventions will enhance understanding more often than they inhibit it.

Descriptions of the Hindi stress pattern also refer to rightmost syllables of 
certain weights, e.g. “stress the rightmost superheavy”. In constructing SPCs, a short 
elipsis “…” will indicate unbounded continuation of a sequence, so that “23..89”, for 
example, designates a pattern placing stress on the nearest heavy syllable (excluding 
syllable 1), or on the farthest syllable if there are no heavy syllables (ignoring syllable 
1). Similarly, “12..78” designates a pattern placing stress on the nearest heavy 
syllable (excluding the farthest syllable, syllable 9), or if none of those syllables are 
heavy, stress falls on the second-farthest syllable (syllable 8).

With these notational conventions, the stress pattern of Hindi is designated by 
the SPC “23..89123..89”. For perspicuity it might be helpful to specifically delimit 
the parts of the SPC referring to different syllable weights by inserting a ‘/’ into the 
SPC, as in “23..891/23..89”. If we take the three levels of syllable weight in this SPC 
to be superheavy, heavy, and light, then this SPC is read as, “Stress syllable 2 if 
superheavy, else syllable 3 if superheavy, ..., else syllable 8 if superheavy, else 
syllable 9 if superheavy, else syllable 1 if superheavy, else syllable 2 if heavy, else 
syllable 3 if heavy, ..., else syllable 8 if heavy, else syllable 9.” Rephrasing, this is 
“Stress the nearest superheavy syllable (excluding syllable 1), else syllable 1 if 
superheavy, else the nearest heavy syllable (excluding syllable 1), else the farthest 
syllable.” Syllable 1 will be stressed only if it is superheavy and all other syllables
are lighter. If syllable 1 is light or heavy (but not superheavy) and all the other syllables are light, stress falls on syllable 9.

Some additional examples of SPCs are given in (11), along with corresponding conditional statements and names of some of the languages exhibiting each stress pattern. The SPC notation will be used occasionally in Chapters 2 and 3, which focus on relatively simple stress patterns. Chapter 4, however, will use SPCs extensively in analyzing the typology of stress patterns produced by the NMC model of primary stress. Refinements to the SPC notation are made in Chapter 5 in order to code stress patterns in which the location of primary stress depends on the location of metrical feet or rhythmic secondary stresses (these refinements are summarized at the beginning of appendix D).

(11)

<table>
<thead>
<tr>
<th>SPC</th>
<th>Location of Primary Stress</th>
<th>Sample Languages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>Dakota, Spanish, Polish</td>
</tr>
<tr>
<td>23</td>
<td>2 if heavy, else 3</td>
<td>Latin</td>
</tr>
<tr>
<td>123/23</td>
<td>1 if superheavy, else 2 if superheavy, else</td>
<td>Manam</td>
</tr>
<tr>
<td></td>
<td>3 if superheavy, else 2 if heavy, else 3</td>
<td></td>
</tr>
<tr>
<td>12.89</td>
<td>nearest heavy, else 9</td>
<td>Komi, Eastern Cheremis</td>
</tr>
<tr>
<td>12.89/1</td>
<td>nearest heavy, else 1</td>
<td>Mongolian, Russian, Mayan</td>
</tr>
</tbody>
</table>

With a notation for describing primary stress in hand, the following chapters take up the task of accounting for the patterns of primary stress observed in human languages. The account will be framed in terms of competition between syllables for stress, with phonological, morphological, and lexical constraints on the location of primary stress. One phonological constraint favors stress on heavy syllables over stress on light syllables. Another phonological constraint on stress determines the effect of linear order on the competition for primary stress. Stress may be favored on syllables earlier in a word or on syllables later in a word, on a language-specific basis.

Morphological structure influences the competition for primary stress by favoring or disfavoring stress on syllables near particular (language-specific) morphological edges. Finally, the lexicon may favor or disfavor stress on particular vowels which surface with idiosyncratic stress or lack thereof. Together, these constraints account for the culminativity and directionality of primary stress, and also account for influence on the location of stress due to syllable weight, morphological structure, and the lexicon.
**Chapter 2:**

This chapter develops a set of constraints on the eligibility of vowels to bear stress. These constraints will initially be used in conjunction with the End Rule to account for a variety of stress systems in which primary stress falls within a few syllables of the beginning or end of a word. The same constraints on eligibility will account for a much wider range of stress systems when the End Rule is replaced by a more general directional prejudice mechanism in Chapter 4.

The proposed constraints on stress eligibility are similar to the local constraints on prominence proposed by the Dynamic Linear Model of stress (Goldsmith, 1991; 1992; 1993; Larson, 1992), with two key differences. An underlying prominence constraint is added so that lexical entries can influence the eligibility of vowels to bear stress—this will account for lexically-idiosyncratic stress patterns. In addition, the very general positional bias mechanism of the DLM is replaced with a more constrained device based on gradient biases associated with the edges of certain morphological constituents (typically words). The restricted theory of positional biases accounts for the fact that edge-oriented stress is generally confined to a three-syllable window at the beginning or end of a word.

I begin by reviewing some of the problems associated with the DLM, with an aim towards adopting key insights of the DLM while avoiding its weaknesses. I will then describe adaptations of the DLM’s local constraints on prominence which will be employed in the NMC theory of primary stress.

2.1. What’s Wrong with the DLM?

The appeal of the DLM is that it derives rhythmic alternations of prominence from fundamental properties of the way adjacent syllables compete for stress. Rhythm emerges from cooperative interactions between syllabic elements, without a supervising code or program which directly stipulates the allowable configurations of rhythm. However, the DLM also has its shortcomings. Prince (1993) analyzes the behavior of the DLM under various parameter settings. He concludes that “the DLM marks a real advance in the direction of finding new principles of linguistic form, and therefore deserves careful analysis and vigorous extension” (Prince, p. 19). Nevertheless, Prince shows that the DLM fails to produce some basic stress patterns, while at the same time producing other patterns which are decidedly uncharacteristic of human languages. Some of the shortcomings noted by Prince are reviewed below.

Under some parameter settings, the DLM will place a single prominence peak exactly in the middle of a word, no matter how long it is. Under other parameter settings the DLM will produce alternating patterns of stress beginning at each edge and working towards the middle (in words with an even number of syllables, this produces a pair of adjacent stresses in the middle of the word, e.g. ơơơơơơ). The ability to place stress, or anything else, right in the middle of a word of arbitrary length is untested in human language and is generally assumed to be beyond the capability of the language system.

The DLM also exhibits length dependencies which are uncharacteristic of real stress patterns. For example, one set of parameters will produce the stress patterns shown in (1); these patterns are from Prince (p. 17). The general pattern here is stress on even-numbered syllables. However, in words of length 6 and 8, stress falls on the initial syllable instead of the second syllable. This type of dependence on absolute length is untested in human languages.

---

1A number of languages exhibit a binary distinction between “short” and “long” words in assigning primary stress. Icuã Tupi, for example, exhibits “3R” stress in words of 5 or more syllables, and “2R” stress in words of 4 or fewer syllables (Hyman, 1977
The ability to produce patterns unlike those observed in human languages suggests that the DLM is an inadequate model of stress. Prince notes that these behaviors are direct consequences of the way the DLM computes the influence of each syllable on its neighbors. Specifically, the problem is that interactions between syllables in the DLM are additive—that’s what makes it a linear model. Prince concludes that stress assignment cannot be a matter of simple linear competition between syllables. Or can it? Unnatural prominence peaks produced by the DLM, or any other model of stress, are not a liability if some other aspect of the model distinguishes between natural patterns (those which do occur in human languages) and unnatural patterns (those which are uncommon or impossible in human languages). In the case of the DLM, it’s not clear whether some unexplored aspect of the model distinguishes the natural from the unnatural patterns of prominence. For the NMC model, however, I suggest in Chapter 4 that the naturalness of a stress pattern depends on the parameter values required to generate it (the magnitude of the parameter values and the precision with which they must be set), and in part on the margin of victory by which one syllables beats other syllables in the competition for prominence. These considerations distinguish between attested and unattested stress patterns which can theoretically be produced by the NMC model.

In addition to the concerns raised by Prince, there is another problem with the DLM which was mentioned in Chapter 1. The DLM is a metrical model of stress. It is fairly successful at producing rhythmic patterns of prominence corresponding to secondary stresses (subject to the limitations described above). However, the DLM assumes that primary stress assignment is a matter of computing secondary stress plus something else. As I argued in Chapter 1, that kind of bottom-up perspective is simply inadequate for many primary stress systems. What makes the DLM good at computing rhythmic patterns of prominence and virtually useless for assigning primary stress is that, in the DLM, interactions between syllables are strictly local—each syllable competes only with its nearest neighbor on the left and the right. Primary stress is culminating—it makes a single syllable prominent relative to all other syllables in the word. If this is to be done via a competition for prominence, it must be a winner-take-all competition between all syllables in the word. Just this kind of competition will be proposed in Chapter 4.

Having isolated the fundamental problems with the DLM and seen that they are a consequence of the linear interactions between syllables, I will set those interactions and the attendant problems aside and focus on local constraints on the prominence of individual vowels. The DLM distinguishes between ‘inherent’ and ‘derived’ activation for each syllable: inherent activation represents the combined effect of local constraints on the stress of individual vowels (e.g. from syllable weight and position with a word); derived activation measures how well a syllable fairs in competition for prominence with its left and right neighbors. Similar concepts are central to the NMC model of stress, but I will employ different nomenclature to avoid the confusion which can result from having two different kinds of ‘activation’.

<table>
<thead>
<tr>
<th>Length</th>
<th>Stress Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>σ'</td>
</tr>
<tr>
<td>4</td>
<td>σ' σ'</td>
</tr>
<tr>
<td>6</td>
<td>σ' σ' σ'</td>
</tr>
<tr>
<td>8</td>
<td>σ' σ' σ' σ'</td>
</tr>
<tr>
<td>10</td>
<td>σ' σ' σ' σ' σ'</td>
</tr>
</tbody>
</table>

Such stress patterns can be analyzed in terms of edge effects, however, and therefore don’t involve a dependence on absolute length of the sort exemplified in (1).
I adopt the term ‘stress eligibility’ to refer to the combined effect of local constraints on the prominence of individual vowels. The DLM had two types of local constraints on prominence: syllable weight and positional biases. The syllable weight constraint will be adopted into the NMC wholesale. Positional biases will be severely restricted so that the amount of positional bias for a particular vowel will be a simple function of the strength of the bias and the distance that vowel is from the edge. These restricted positional biases will be referred to simply as ‘edge biases’. In addition, a third constraint will be added to the eligibility of a vowel to bear stress. ‘Underlying prominence’ specifies lexically-idsyncratic tendencies for certain vowels to be stressed or unstressed. As in the DLM, nonmetrical constraints are given gradient numerical weights—this allows a small number of interacting constraints to produce a wide range of stress patterns. Gradient constraints also account for degrees of lexical deviations from the default stress pattern of a language—this is crucial to the analysis of lexical stress in Spanish presented in Chapter 3.

To set the overall framework for these local constraints on the eligibility of individual vowels to bear stress, I will first define the notion of stress eligibility. The rest of the chapter will then be devoted to the relationship between stress and edges, and how best to represent that relationship as a constraint on stress eligibility.

2.2. Eligibility for Stress

In conventional metrical theory, the End Rule can be invoked by a language to place stress on the rightmost or leftmost stressable element on some level of the metrical grid (Prince, 1983). If the End Rule is applied at the syllable level, the edgemost syllable will be stressed. If the End Rule is applied at the foot level, the head of the edgemost foot will be stressed at the next level of the grid (the primary stress level). All elements on the relevant grid level are stressable except a single element at the edge of the stress domain may be rendered ineligible by virtue of being extrametrical.

In this chapter and the next I will take stressable element to mean a vowel which is eligible to bear stress. Stress eligibility will be computed by simply adding together the strength of the relevant constraints for each vowel, as specified in (2). The End Rule will then be used to assign stress to the rightmost or leftmost eligible vowel. Conceptually, extrametricality renders phonological material invisible to stress rules, as if by magic. Constraints on eligibility derive apparent extrametricality from interactions between more basic constraints, providing an explanation of extrametricality-type edge effects in terms of more general lower-level constraints.

(2) Stress eligibility of syllable i: 
\[ E_i = W_i + P_i + \sum G_j^j \]

where 
- \( W_i \) = syllable weight = \( L \) for light syllables
- \( P_i \) = underlying prominence
- \( G_j^j \) = bias from edge \( j \)

The three types of constraint on stress eligibility will be discussed below. To determine the eligibility of a vowel to bear stress, each constraint will be assigned a numeric strength: a positive constraint strength indicates a preference for stress on a vowel; negative strength indicates a constraint against stress. The exact values of the constraint strengths are not meaningful in and of themselves (the units are arbitrary)—what matters is their values relative to each other. For each vowel, the strengths of the relevant constraints are added together to determine a vowels’ stress eligibility. If the total constraints for stress on a vowel are greater than the constraints against stress, the stress eligibility will be greater than zero, and the vowel is eligible to bear stress. Otherwise, the vowel is not eligible to bear stress.
The relative strengths of syllable weight, underlying prominence, and edge biases determine the stress eligibility of each vowel. These factors, together with directional prejudice, developed in Chapter 4, comprise the nonmetrical constraints on stress.

**Syllable weight**

In many stress systems, the location of stress is sensitive to syllable structure, so that perceptually prominent syllables attract stress more strongly than others. The degree to which a certain type of syllable structure attracts stress is referred to as the weight of a syllable: heavy syllables attract stress more strongly than light syllables. As discussed in Chapter 1, a variety of factors can influence syllable weight, including tone, vowel length and height, and the presence of an onset or coda. In order to capture the generalization that heavier syllables more strongly attract stress, I adopt a simple SYLLABLE WEIGHT constraint on stress eligibility. This is a gradient constraint which increases the eligibility of a vowel to bear stress in direct proportion to the weight of the syllable it’s in. Vowels in heavy syllables will generally be more eligible to bear stress than vowels in light syllables.

In general, a stress system may be sensitive to several levels of syllable weight, as in Pirahê, discussed in Chapter 1. Nevertheless, a simple binary distinction between heavy and light syllables is sufficient for many languages, and I will focus primarily on this simpler situation in order to explore more fully interactions between syllable weight and other constraints on stress. I abstract away from details of syllable structure relevant to the syllable weight distinctions in particular languages, and simply refer to light versus heavy syllables. Whereas Hayes (1995) distinguishes between weight due to moraic quantity and weight due to the more general notion of perceptual prominence, I will limit my discussion to the more general notion of weight as prominence. This is intended merely to limit the scope of the current endeavor, and is not a theoretical claim that moraic quantity doesn’t matter.

I will borrow an insight from moraic phonology, though, as a starting point in dealing with syllable weight. In moraic representations, the distinction between light and heavy syllables most often corresponds to monomoraic light syllables versus bimoraic heavy syllables. I will tentatively assume a 2:1 ratio between the weight of heavy and light syllables. I assume that the syllable weight constraint is always positive, but that the strength of the weight constraint for heavy syllables is twice the strength of the weight constraint for light syllables.

**Underlying prominence**

Many languages have lexical exceptions, words which deviate idiosyncratically from the canonical stress pattern of the language. These lexical exceptions will be referred to as cases of lexical stress, not because the location of stress in these forms is literally marked in the lexicon, but because the location of stress is influenced by information in these lexical entries. Cases of lexical stress will be accommodated by assigning underlying prominence to certain vowels in the lexical entries of the exceptional forms. This underlying prominence will then be treated as just one more constraint on the eligibility of those vowels to bear stress. Underlying prominence will be discussed in some detail in the discussion of lexical exceptions in Polish and Spanish in Chapter 3. Outside those discussions, lexical stress will generally be ignored and I will focus on a wide range basic default patterns of stress, i.e. patterns which are generated by the other constraints in the absence of underlying prominence.

**Positional biases**

In addition to syllable weight and underlying prominence, the eligibility of a vowel to bear stress also depends on its location within particular morphological domains
(most often the word). The DLM simply stipulated a positional bias for the $n$th syllable of a word (cf. Goldsmith, 1992). This is a very powerful mechanism which can just as easily place stress on the fourth or fifth syllable from the beginning or end of a word as on the first or second syllable from the edge. In real stress patterns, it is quite common for stress to be assigned one or two, or at most three syllables from an edge. It is exceedingly rare for stress to be assigned to the $n$th syllable from an edge, where $n$ is greater than 3.\footnote{Odawa is a notable exception to the three-syllable stress window. In this dialect of Ojibwa, primary stress falls on the antepenultimate stressed vowel, which may be 3, 4 or 5 syllables from the end of the word ([Halle, 1987 #11:183]; [Hayes, 1995 #122:216]). However, Odawa is one of the languages in which secondary stress evidently is established prior to primary stress (Odawa is like Cairene Arabic, Asheninca, and some dialects of Hindi in this respect), and I will have nothing further to say about it. Other languages which are apparent exceptions to the three-syllable stress window include: Palestinian Arabic, in which stress falls either three or four syllables from the end in words ending in a sequence of three light syllables ([Hayes, 1995 #122:126]); Paamese, with preantepenultimate lexical exceptions to regular antepenultimate stress ([Goldsmith, 1990 #5:216], [Hayes, 1995 #122:178]).} As Hayes put it, “the rule ‘stress the fourth syllable from the end’ appears to be completely unattested” (Hayes, 1995:314). The positional bias mechanism of the DLM makes it too easy to place stress outside the crosslinguistic three-syllable stress window. I argue below that a more restricted theory is appropriate, based on the observation that stress is sensitive to the edges of morphological domains.

In many languages, stress is assigned relative to one edge of a word, but not necessarily on the edgernost vowel. In languages with penultimate stress, like Spanish or Polish, stress is retracted one syllable from the end of the word.\footnote{Deviations from penultimate stress in both Spanish and Polish are discussed in chapter 3.} In languages with antepenultimate stress, like Macedonian or Paamese, stress is retracted two syllables from the end of the word. In Fijian, stress is either final or penultimate, depending on the weight of the final syllable. In Latin, stress is retracted either one or two syllables from the end of the word, depending on the weight of the penult.\footnote{Additional complications in Latin stress are introduced by stressless clitic suffixes, which are discussed in chapter 3.} These stress systems form a scale according to how far the stressed vowel is from the end of the word. These patterns by no mean exhaust the possibilities for primary stress, but they do comprise the set of stress patterns which can be analyzed on this simple scale of increasing distance between stress and the edge of a word. More complex patterns are discussed in Chapter 4. Stress patterns which consistently count more than three syllables from the edge of a word are unattested (though stress may fall more than three syllables from the edge in unbounded stress systems and in systems which place stress a fixed number of feet, as opposed to syllables, from the edge).
The stress patterns in (3) can be accounted for in metrical theory, but only if the theory is augmented with metrical theory, but only if the theory is augmented with extrametricality. This minor redundancy has been discussed elsewhere in the literature, and I will not pursue it here.

Primary stress in many languages cannot be assigned using only independently-motivated devices of rhythmic stress (e.g. Hayes’ limited foot inventory). In order to assign primary stress three syllables from the edge, using feet plus the End Rule, it is necessary either to let feet include more syllables, or to skip over the edgemost syllable when building feet. If Universal Grammar makes available an inventory of feet including various combinations of, say, three syllables, then we would expect those feet to play a role in word-internal patterns of rhythmic prominence (cf. Hayes 1981). Since word-internal rhythmic patterns of prominence do not require such feet, we conclude with Hayes that such feet are poorly motivated and we look for an alternative mechanism for assigning primary stress.

One alternative is to extend the reach of rhythmic constituents relative to the edge of a word by using feet in conjunction with extrametricality. In metrical theory, extrametricality allows a phonological constituent (a segment, mora, syllable, etc.) at the edge of the stress domain to be ignored by stress rules. This effectively renders certain syllables ineligible to bear stress. If the extrametrical constituent is smaller than a syllable, e.g. a segment, mora, or syllable rime, then edgemost syllables are effectively “demoted one position down the hierarchy of syllable weight” (Hayes, 1982:229). If the extrametrical constituent is an entire syllable, stress is forced one syllable farther from the edge than it would otherwise be. In combination with binary feet, extrametricality will allow stress to fall on either the penultimate or antepenultimate syllable, as shown in the bottom half of (4). As shown, penultimate stress may be generated either directly with a left-headed foot, or by a right-headed foot combined with extrametricality. This minor redundancy has been discussed elsewhere in the literature, and I will not pursue it here.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Language} & \text{SPC} & 4 & 3 & 2 & 1 \\
\hline
\text{Weri} & 1R & XXXX & \text{---} & \text{---} & \text{---} \\
\text{Fijian} & 12R & \text{---} & \text{---} & \text{---} & \text{---} \\
\text{Polish} & 2R & \text{---} & \text{---} & \text{---} & \text{---} \\
\text{Latin} & 23R & \text{---} & \text{---} & \text{---} & \text{---} \\
\text{Paaman} & 3R & \text{---} & \text{---} & \text{---} & \text{---} \\
\hline
\end{array}
\]

Languages with stress on the rightmost eligible vowel form a scale according to the distance between the stressed vowel and the end of a word. Stress is marked in words with all light (L) syllables, all heavy (H) syllables, or with syllables of arbitrary weight (X) if stress falls on the same syllable regardless of syllable weight.

The stress patterns in (3) can be accounted for in metrical theory, but only if the theory is augmented with theoretical machinery beyond that motivated by rhythmic stress patterns. In accounting for actual rhythmic patterns of stress, only a limited set of feet are needed. Hayes (1995) maintains that only 3 different types of feet are required. Other works have arrived at slightly different foot inventories, but there is a consensus that only a very limited set of foot templates is required, and these are generally restricted to a maximum of two syllables (for reasons articulated in Hayes, 1981). Although a limited inventory of foot types is adequate for rhythmic patterns of stress, primary stress is less cooperative. Figure (4) shows the types of feet necessary for bottom-up assignment of the stress patterns shown in (3). The feet here are based on Hayes’ foot inventory (cf. Chapter 1). If feet are maximally bisyllabic and the head of the edgemost foot bears the primary stress, then there is no way to place stress more than two syllables from the edge of a word. This is illustrated in the top half of (4).
By introducing the device of extrametricality, metrical theory is able to account for primary stresses more than two syllables from the edge of the word without expanding the set of allowable feet. There is another alternative, however, in which the patterns of primary stress in (3) do not involve metrical feet at all. The languages in (3) can all be treated as instances of End Rule stress applied at the syllable rather than the foot level, given an appropriate mechanism for rendering certain vowels near the edge unstressable. The key idea is that in each of the languages in (3) there is a narrowly circumscribed relationship between stress and the end of a word. Speakers of these languages “know” that stress in their language is close to the end of a word, but not too close.

Maximally bisyllabic feet, combined with single-syllable extrametricality, can place stress no farther than three syllables from the edge of a word.

In metrical theory, extrametricality has the effect of pushing stress away from the edge of the stress domain. The Peripherality Condition restricts extrametricality to a single constituent at a designated edge (left or right) of its domain (cf. Hayes, 1995:57 and references therein). Nevertheless, a whole scale of extrametricality effects are observed, ranging from segment extrametricality up to syllable and even foot extrametricality. The number of segments rendered invisible to stress increases as extrametricality is applied at higher levels of phonological structure. This scale of extrametricality effects can be reinterpreted in terms of a gradient constraint or bias against stress at the edge of a word. This constraint, this edge bias, neutralizes some or all of the weight of the syllables closest to the edge. This constraint represents the knowledge that stress is not too close to the relevant edge. The strength of the constraint determines the distance between stress and the edge of a word.

Like consonant or mora extrametricality, a weak edge bias has a relatively small effect, primarily on the edgemost syllable. Like syllable, a stronger edge bias renders the final syllable ineligible for stress. An even stronger constraint against stress at the designated edge will render the penultimate as well as the final syllable ineligible for stress. This is similar in effect to foot extrametricality, but it doesn’t depend on the prior construction of metrical feet. Combining a very strong edge bias with the End Rule will therefore provide a top-down account of antepenultimate stress like that of Paamese or Macedonian.

---

3One argument for the Peripherality Condition involves the apparent revocation of extrametricality when suffixation results in an expanded stress domain so that a previously-extrametrical syllable is no longer in edgemost position. See the discussion of Latin in chapter 3 for a reanalysis of clitic stress in Latin which has previously been analyzed as involving revoked extrametricality.
Like the scale of extrametricality effects, an edge bias must produce a range of effects near the edge of the stress domain. However, we do not want to simply let an edge bias arbitrarily render any number of syllables ineligible for stress—this would be a much less constrained device than extrametricality as employed in metrical theory. Pursuing the idea that extrametricality effects result from a constraint against stress near a designated edge, I suggest that this constraint projects its influence against stress inward from the edge of the word, with diminishing effectiveness at increasing distances from the edge. This is a gradient edge bias.

We now have at least a vague, qualitative description of edge biases. These biases will allow the End Rule to place primary stress at various distances from one edge of the stress domain, without requiring prior foot construction. In order to formalize the notion of edge bias enough for it to be useful, I will entertain the hypotheses in (5).

(5) Edge Effect Hypotheses

a. Distance—The eligibility of a syllable to bear stress depends on the distance between the syllable and certain phonological or morphological edges
b. Locality—Edges have the greatest effect on syllables close to the edge, and little or no effect on syllables far from the edge
c. Uniformity—The only parameter of variation between edge biases within or across languages is the strength; other characteristics of edge biases are universal (e.g., how fast the effect drops off as distance from the edge increases)

In general, morphological structure affects the prominence of syllables within a small neighborhood of edges. This insight is embodied in the Distance and Locality Hypotheses. Stress is either attracted to or retracted from the left or right edge of relevant constituents (the analyses of Spanish and Latin in Chapter 3 involve simultaneous attraction to the edge of one morphological constituent and retraction from the edge of a larger constituent, for example). The effect of edges on stress is the basis for traditional principles of stress assignment like the End Rule, which assigns stress to the rightmost or leftmost element (Prince, 1983), and extrametricality, which ignores an edgemost element (Hayes, 1981). In Optimality Theory, the same insight underlies constraints like EDGEMOST, ALIGNMENT, or NONFINAL (McCarthy & Prince, 1993a, 1993b; Prince & Smolensky, 1993). EDGEMOST or ALIGNMENT constraints align phonological and morphological edges as closely as possible. NONFINAL militates against stress in absolute edgemost position.

The Uniformity Hypothesis constrains the theory by requiring a single type of edge bias to account for all edge effects. This will play a crucial role in arguments below about the possible shape of edge biases. Using these hypotheses to constrain the theory, the next two sections explore the possibility of using the functions illustrated in (6) to model edge biases. The linear ramp function of (6A) will be discussed first, and then the gaussian bell-curve of (6B) will be considered. The gaussian curve provides a better model of edge effects, and it is employed for all edge biases in subsequent chapters.

(6) Generic Edge Bias

A

<table>
<thead>
<tr>
<th>Ramp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height=</td>
</tr>
<tr>
<td>Slope=m</td>
</tr>
</tbody>
</table>

B

<table>
<thead>
<tr>
<th>Gaussian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height=</td>
</tr>
<tr>
<td>Width=g</td>
</tr>
</tbody>
</table>

Ramped Edge Biases

The simplest type of edge bias consistent with the Locality Hypothesis (5b) is based on a ramp function. The unit ramp, taken as a function of \( t \), has the value 0 for \( t < \)
0, and the value t for t > 0 (cf. Dorf, 1983:110, for example). The key aspect of this function is that it has two intersecting regions of behavior: one region in which it is flat (t < 0), and one region in which it is a straight-line function of the independent variable (t > 0). I will not formalize the transformations required to derive the ramped edge bias shown in (6A) from the unit ramp function.

A ramped edge bias has the greatest magnitude at the edge, and decreases in magnitude at a constant rate toward zero as the distance from the edge increases. Beyond a certain distance from the edge, the strength of the bias is zero (this corresponds to the flat part of the unit ramp). A ramped edge bias can be characterized by two values, the strength and the slope. The bias strength is the effect of the bias on the edgemost syllable. The bias slope determines how fast the effect of the bias falls off as the distance from the edge increases. The Uniformity Hypothesis (5c) maintains that the slope for all edge biases is fixed, but at what value?

Specific stress systems can be characterized in terms of where stress falls in a word with all light syllables (an Lword), and where stress falls in a word with all heavy syllables (an Hword). For each vowel in a word, the effect of the edge bias on the vowel is added together with syllable weight to determine the vowel’s stress eligibility. The ramped edge bias lowers the eligibility of vowels near the edge. Since light syllables start out with less eligibility due to syllable weight than heavy syllables, light syllables can be rendered ineligible more easily by an edge bias, so the edgemost eligible vowel in Lwords will always be at least as far from the edge as the edgemost eligible vowel in Hwords. If stress is assigned to the edgemost eligible vowel, stress will be at least as far from the edge in Lwords as in Hwords. This is very promising considering the typology of stress patterns in (3).

The particular pattern of stress assignment depends on the strength of the edge bias. For convenience I will discuss stress systems assigning stress at the right edge, the end of the word. The analysis extends very easily to produce the mirror image stress patterns at the beginning of the word. If there is no edge bias at all, stress will always fall on the final syllable, whether it’s light or heavy. If the edge bias is just strong enough to counteract the weight of a light syllable, final light syllables will be ineligible for stress but final heavy syllables will still be eligible. This will produce the quantity-sensitive stress “12R” system, with stress on the final syllable if it is heavy, or else on the penultimate syllable. This pattern (or its mirror image “12L”) corresponds to the patterns of Ossetic, Rotumen, and Ulwa. If the edge bias is strong enough to counteract the weight of a heavy syllable, the final syllable will never be stressed. Stress will fall farther from the end of the word, depending on the pattern of syllable weight and the slope of the edge bias. The stress patterns shown in (3) represent a typology of patterns produced by a scale of edge bias values. With a stronger edge bias, stress is pushed farther from the edge of the word (assuming the edge bias is negative), because more syllables near the edge will be rendered ineligible for stress. Figure (7) shows how the number of ineligible syllables near the edge increases as the edge bias becomes more and more negative. The strength of the edge bias in (7) is measured in terms of the weight of a light syllable. In these units, a bias of strength –1 will exactly counteract the weight of a light final syllable. In that case stress would fall on the penult if the final is light, or on the final syllable if it is heavy. A bias of strength –2 will exactly counteract the weight of a heavy final syllable. The influence of such an edge bias on syllables farther from the edge depends on the slope as well as the strength of the edge bias.

Unfortunately, the simple ramped edge bias readily allows stress to be placed on the fourth, fifth, or even sixth vowel from the edge of a word. If three vowels at the edge of the stress domain are ineligible for stress, the End Rule will place stress on the fourth
from constraints on learnability rather than some intrinsic constraint on possible stress patterns. Nevertheless, in the absence of a detailed theory of phonological learning, I will propose an alternative to the ramped edge bias which will offer a principled explanation for the three-syllable window. The alternative is to assume edge biases are nonlinear.

**Gaussian Edge Biases**

The familiar bell curve of “normal” statistical distributions is described by a gaussian function. A gaussian function is a plausible alternative to the ramp, and one which has the potential to account for the crosslinguistic three-syllable stress window. A generic gaussian edge bias is shown above in (6B). The gaussian edge bias is relatively flat near the edge, then drops off quickly almost to zero and flattens out again. Gaussian edge biases can be described by the equation $G_i = \left[ \frac{G_0}{\sigma} \right]^{-\frac{(k-i)^2}{2\sigma^2}}$. $G_i$ specifies the effect of the edge bias on vowel $i$, $|G_i|$ specifies the strength of the edge bias, i.e. the effect of the edge bias on the edgemost vowel. The constant $\sigma = 2.71$ is the base of the natural logarithm. The parameter $\sigma$ determines the width of the bell curve (in statistical terminology, the standard deviation). The distance from the edge is measured by $(k-i)$, the distance between vowel $i$ and the edgemost vowel, $k$. Formalized this way we can number vowels from either end of the word. If the leftmost vowel is taken to be number 1, the third vowel will be number 3 and the distance between the third vowel and the first will be 2. In a 6-syllable word, the last vowel is number 6, the antepenultimate vowel is number 4, and the distance between them is 2.

If $|G_i|$ is negative, the eligibility of vowels near the edge will be reduced. The eligibility of light and heavy syllables can be computed as a continuous function of the distance from the edge, as shown in (8). Heavy syllables are inherently more eligible than light syllables; hence, the eligibility curve for a heavy syllables is above that for light syllables. Distance from an edge is measured in syllables, with vowels at integer
values of distance from the edge. If stress is assigned to the edgemost eligible vowel, it will fall on the vowel corresponding to the smallest integer greater than the point where the eligibility curve becomes positive (i.e., where it crosses the horizontal axis). The weight difference between light and heavy syllables means that the crossover point from ineligibility to eligibility will be farther from the edge for light syllables than for heavy syllables.

If there is an integer value between the eligibility crossover points for heavy and light vowels, as in (8A), the location of stress will depend on syllable weight. In (8A), the edge bias is strong enough to render the edgemost syllable ineligible for stress, whether it’s light or heavy. The second syllable from the edge is eligible for stress is it’s heavy, but not if it’s light. If there is no integer value between the two crossover points, as in (8B), the location of stress will not depend on syllable weight. General equations for computing the crossover points and the edgemost eligible vowel are given in Appendix A.1.

According to the Uniformity Hypothesis, the width of gaussian edge biases should be fixed universally, but at what value? We can narrow the range of plausible candidates by considering converging evidence from attested stress patterns. The existence of penultimate stress languages places an upper bound on the value of \( g \). The existence of languages with antepenultimate stress places a practical lower bound on the value of \( g \). I will discuss those bounds, and then adopt a value for \( g \) near the middle of the range defined by the upper and lower bounds.

**Penultimate Stress**

A number of languages exhibit quantity-insensitive (QI) stress on the second syllable from the edge, including Lakota and Paiute with stress on the second syllable of a word, and Polish, Warao, Indonesian and Spanish, with stress on the penultimate syllable. There are two ways to deal with the distinction between quantity-sensitive and quantity-insensitive languages. The approach which is usually taken in metrical accounts of stress is to make quantity-sensitivity a fundamental parameter which can be set on a language-specific basis. I will take a different approach, based on the assumption that the perceptual prominence associated with different syllable shapes is a universal characteristic of those syllable shapes. Apparent quantity-insensitivity results when the constraints on stress eligibility place stress the same distance from the edge of a word regardless of the weight of the syllables in the word. QI penultimate stress requires a negative edge bias strong enough to render the final vowel ineligible for stress, whether it’s in a heavy or light syllable. At the same time, the effect of the edge bias on the penultimate vowel must be small enough so that even a light penult is eligible for stress. This requires a fairly narrow edge bias, so that the effect of the bias is significantly smaller on the penult than on the final vowel.
If the weight of a heavy syllable is twice the weight of a light syllable, then quantity-insensitive stress can be achieved only if \( g < 0.849 \) (see appendix A.2). With a wider edge bias, any bias strong enough to prevent stress on a final heavy syllable will also render a light penult ineligible for stress. Stress could fall on the penult in Hwords, but would fall farther from the edge in Lwords. If the width of a gaussian edge bias were greater than about 0.849, quantity-insensitive penultimate stress would simply be impossible to produce with this model of stress.

**Antepenultimate Stress**

Languages like Macedonian and Cayuvava place stress on the third syllable from the edge, regardless of the shape of the syllable (Hayes, 1995 #122:205). QI antepenultimate stress requires a negative edge bias strong enough to render both the penult and the final vowel ineligible for stress. At the same time, the effect of the edge bias on the antepenultimate vowel must be small enough so that a light antepenult is eligible for stress. If edge biases are relatively wide, the effect of an edge bias on the penultimate syllable will be just a little less than on the final syllable. On the other hand, if edge biases are relatively narrow, the effect of a bias on the penult will be much smaller than on the final syllable, and a very strong bias will be required to render a penultimate syllable ineligible for stress.

It’s plausible to assume that greater cognitive resources are required for stronger (positive or negative) constraints. This assumption is implicit in many connectionist models of cognitive or perceptual processes, where connection weights (i.e. constraints between nodes in a network) typically start off small and become stronger as learning progresses. It takes more training to acquire stronger constraints. Moreover, if a constraint like an edge bias is ultimately realized in the neural network of the brain, a stronger constraint between morphological structure and the location of stress will require more or stronger neural pathways, i.e. greater biological, as well as cognitive, resources. The simplest thing is no constraint at all, i.e. a strength of zero.

If the strength of edge bias required is a measure of the difficulty of acquiring or using a particular stress system, then languages which require very large edge biases should be relatively uncommon. It may be reasonable to suppose that the strength of edge bias required to produce antepenultimate stress is no greater than, say, 10 or 15 times the weight of a heavy syllable. This would require \( g > 0.5 \) (see appendix A.3). If \( g \) is actually about 0.7, antepenultimate stress would require \( ||g|| \) to be 2.7 times as strong as the weight of a heavy syllable. On the other hand, if \( g \) were much smaller than 0.5, say 0.3, \( ||g|| \) would have to be more than 250 times as strong as the weight of a heavy syllable. If stronger biases correspond to less favored (more marked) stress systems, a configuration like this would be highly disfavored, and we would not expect to find antepenultimate stress attested in natural languages.

Taken together, the existence of QI penultimate and QI antepenultimate stress systems suggests that the universal edge bias width, \( g \), lies somewhere between 0.849 and about 0.5. For the remainder of this work I will adopt the value \( g = \frac{1}{\sqrt{2}} = 0.7 \). This value lies squarely within the range of plausible values derived above, and will simplify the computation of edge biases slightly. With this value of \( g \), gaussian edge biases can be described by the equation \( G_i = ||g||^{(k-i)^2} \), where \((k-i)\) is the distance between vowel \( i \) and the edgemost vowel, as before.

Having settled on a reasonable value for the width of gaussian edge biases, we are in a position to examine the range of stress systems which result from various amounts of edge bias combined with the End Rule. It will be convenient to define several measures related to stress eligibility:
‘eligibility of a vowel’ is the sum of constraints on eligibility for a particular vowel, including syllable weight, relevant edge biases, and underlying prominence, if any.

‘eligibility of a word’ will be defined as the eligibility of the stressed vowel in a particular word or word form (this will always be a positive quantity).

‘Word’ here might be either a specific word of some language, or an abstract word form, like an Lword or an Hword.

‘eligibility of a stress system’ will be defined as the lowest among the eligibilities of all relevant word forms; typically this will be the eligibility of an Lword or the eligibility of an Hword, whichever is lower; In a stress system with only negative edge biases, the eligibility of the stress system will never be greater than L (assuming stress is assigned by the End Rule).

‘potential eligibility of a stress system’ will be defined as the difference between L (the maximum possible eligibility) and the actual eligibility of the stress system. This is a measure of how close a stress system is to another slightly different stress system.

The effect of combining various amounts of negative edge bias with the End Rule can be represented graphically by plotting the potential eligibility V(G) of the stress system as a function of the edge bias, as in (9). On this graph, troughs correspond to stress systems in which the stressed vowel has very high eligibility; peaks indicate transition regions where the stressed vowel is barely eligible, and where the system shifts from one stress pattern to another with an incremental change in the strength of the edge bias.6

---

6The idea of showing behavioral phase shifts by plotting potential as a function of a control parameter was inspired by Smith & Thelen ([1, 1993 #160]) and Thelen & Smith (1994).
Three-Syllable Window

In metrical theory, binary feet are headed on the left or the right. If a foot is constructed at the right edge of a word, the headedness of the foot affects the proximity of stress to the end of the word. A right-headed foot will place the stress close to the end of the word. A left-headed foot will push the stress farther from the end of the word, possibly subject to quantity-sensitive effects. Combining a binary foot with single-syllable extrametricality restricts stress to the three edgemost syllables. As shown in (10), relatively small edge biases will result in stress on the first, second, or third vowel from the edge, but no further.

In principle, a very large edge bias can render the three edgemost vowels ineligible, resulting in a system with stress on the fourth vowel from the edge. However, the strength of the edge bias required is much larger than the edge biases required for the actually attested stress systems of (10). The amount of edge bias required to push stress two, three, and four vowels from the edge is plotted in (11), both for the value of bias

<table>
<thead>
<tr>
<th>Language</th>
<th>SPC</th>
<th>Edge Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Werć</td>
<td>1R</td>
<td>0</td>
</tr>
<tr>
<td>Fijian</td>
<td>12R</td>
<td>-1</td>
</tr>
<tr>
<td>Polish</td>
<td>2R</td>
<td>-2</td>
</tr>
<tr>
<td>Latin</td>
<td>23R</td>
<td>-2.7</td>
</tr>
<tr>
<td>Paameşe</td>
<td>3R</td>
<td>-5.4</td>
</tr>
<tr>
<td>?</td>
<td>34R</td>
<td>-55</td>
</tr>
<tr>
<td>?</td>
<td>4R</td>
<td>-109</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location of stress (w.r.t. end of word)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>XXXXX</td>
</tr>
</tbody>
</table>

Plots show how strong a negative gaussian edge bias must be in order to push stress a certain distance away from the edge in an Lword. If n syllables are ineligible, the End Rule will assign stress to syllable n+1. Top plot corresponds to a bias with width 0.849, the maximum width at which quantity-insensitive penultimate stress is possible. Bottom plot corresponds to a bias with width 0.707, the intermediate width adopted in the text.
of languages like Lakota, Polish, and Spanish. Even with edge biases this wide, an edge bias of $|G| < -16$ would be required to push stress four syllables from the edge. The crosslinguistic three-syllable stress window is thus accounted for by taking the magnitude of edge bias required for a particular stress system to be an indication of the markedness of that stress system. A gaussian edge bias thus replaces extrametricality and binary feet in accounting for the three-syllable stress window.

2.4. Discussion

Edge biases function as morphological constraints on stress. They capture generalizations about the relationship between particular morphological edges and the occurrence or nonoccurrence of stress on nearby vowels within the corresponding morphological constituent. An edge bias increases or decreases the eligibility of vowels near the relevant edge to bear stress (the current chapter has only explored the effect of negative edge biases, but positive biases will be employed in the discussion of Spanish and Latin in the next chapter). If the effect of an edge bias extends from the edge inward, with a gaussian-shaped decrease in efficacy as a function of distance from the edge, then moderately strong edge biases can place stress one, two, or three syllables from the edge of a word, but no farther. Such edge biases can be used in conjunction with the End Rule to assign primary stress in many languages which have previously been described in terms of bottom-up stress assignment employing binary feet and extrametricality.
the common methodology of basing one’s analysis on the “core” phenomena of a language and only gradually, if ever, extending the analysis to the more “marginal” phenomena can be misleading… exceptions should play a more central role in, rather than function as a footnote to, theoretical analysis.

Inkelas, 1994b:32

Chapter 3:

This chapter examines three languages in some detail in order to illustrate the value of the constraints on stress eligibility proposed in the preceding chapter. Spanish and Polish illustrate the role of underlying prominence in accounting for lexical stress patterns. Spanish and Latin exhibit interactions between morphological structure and stress, and provide useful illustrations of how multiple edge biases can simultaneously affect the eligibility of vowels to bear stress.

Stress is not necessarily sensitive to only one edge at a time. Words often have nested morphological structure, and phonological processes are often sensitive to that structure. This observation underlies notions of cyclic rule application, as well as the distinction between cyclic and noncyclic rules or domains (e.g. Halle & Vergnaud, 1987a). The basic generalization, however, is that phonology is sensitive to morphological structure (Goldsmith, 1993 and references therein). The implication of this for stress assignment is that the location of primary stress may be sensitive to the edges of multiple morphological domains within a word. This idea is pursued in some detail in the discussions of stress in Spanish and Latin.

3.1. Spanish Stress

As mentioned in Chapter 1, Spanish has rhythmic secondary stresses on alternating syllables before the primary stress, as in constantinopolización ‘constantinopolisation’ and constantinopolización ‘constantinopolisationism’ (Roca, 1986:253). Roca (1986; 1991) has argued convincingly on the basis of interactions between stress assignment and syllable structure that primary stress in Spanish must be established before secondary stress. Roca’s conclusion is widely accepted in subsequent works on Spanish stress and I will not review the relevant data here. In nonderivational terms, the factors which determine the location of primary stress in Spanish take precedence over the rhythmic principles which govern secondary stress. Although it is uncontroversial that the assignment of primary stress in Spanish logically precedes the assignment of rhythmic secondary stresses, analyses of Spanish within the theory of metrical phonology continue to employ metrical feet to determine the location of primary stress (e.g. Harris, 1995a; Roca, 1990). In the following sections I suggest that primary stress in Spanish is best analyzed in terms of nonmetrical constraints on the eligibility of vowels to bear stress. In particular, the relationship between primary stress and morphological structure in Spanish will be described in terms of edge biases. When nonmetrical constraints account for primary stress, metrical feet can be reserved for true instances of rhythmic stress.

Primary stress in Spanish most often falls on the penultimate syllable of a word. According to Harris (1992b), some 80% of Spanish surface forms exhibit penultimate stress, including noun forms like those in (1a), and verb forms like those in (1b). In addition, stress in numerous loan words is displaced from its original location in the donor language, producing penultimate stress as in (1c). Finally, Spanish acronyms like those in (1d) are systematically pronounced with penultimate stress. All these facts

out via email and mail correspondence over several years.

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1I am grateful to Jim Harris for thoughtful discussions of Spanish stress carried
support the default status of penultimate stress in Spanish.\textsuperscript{3} In both verbs and nouns, idiosyncratic deviations from penultimate stress are conditioned by specific morphemes. These aspects of Spanish stress will be addressed below.

(1) a. ma.dru.gá.da 'early morning'
   ma.dru.gá.der 'early rising'
 b. ter.mi.ná 'she finishes'
   ter.mi.ná mos 'we finish'
 c. Col.gá.te 'Colgate'
   de.tec.tí.ve 'detective'
 d. CA.NA.CÍN.TRA 'Camara Nacional de la Industria de la Transformación'
   CO.NA.SÚ.PO 'Compañía Nacional de Subsistencias Populares'

The stress patterns of Spanish will be addressed in several parts. I first discuss regular and exceptional (lexically idiosyncratic) stress in Spanish nouns, introducing the notion of underlying prominence and showing how it accounts for various degrees of exceptionality. The analysis of Spanish noun stress also demonstrates how interactions between morphological structure and stress are accounted for in terms of multiple edge biases. Stress generally avoids the very end of a word, but is attracted to the end of noun stems. I then discuss the stress patterns of Spanish verbs, illustrating again the need for two edge biases, and the need for positive as well as negative values of underlying prominence. Finally, the importance of gradience in underlying prominence is demonstrated by considering exceptional words which seemingly violate the general quantity-sensitivity observed in Spanish stress patterns.

3.1.1. Lexical Stress in Spanish Nouns\textsuperscript{3}

While the location of primary stress is predictable in the majority of Spanish words, a sizable number of words deviate idiosyncratically from the canonical pattern of penultimate stress. I will distinguish between words with predictable “default” stress, and words with a stress pattern which is evidently “marked” in the lexicon in some way. To accommodate these latter forms, metrical accounts of Spanish typically mark the lexical entries of the exceptional forms with a diacritic, and invoke a special rule or prevent one of the regular stress rules from applying to those forms (cf. Den Os & Kager, 1986; Harris, 1987, 1995a; Roca, 1988, 1990).\textsuperscript{4} Rather than marking certain forms with a lexical diacritic, I argue that lexical stress in Spanish is better analyzed in terms of an underlying phonological feature reflecting the lack of surface prominence of vowels which are idiosyncratically unstressed. This underlying prominence interacts with edge biases to account for lexical stress in Spanish.

\textsuperscript{3}An earlier version of this analysis of Spanish nouns appears in Bailey (\textit{1}, 1996 #198).

\textsuperscript{4}Harris (\textit{1}, 1983 #12) gives an account of Spanish stress which does not rely on rule-invoking or rule-blocking diacritics. However, the lexically-marked extrametrical vowels employed in Harris’ analysis require a rather strained interpretation of the Peripherality Condition on extrametricality. See Den Os & Kager (\textit{1}, 1986 #31) for further discussion.
As noted above, penultimate stress is the default in Spanish. One large class of exceptions to this generalization is predictable on the basis of morphological structure. Most singular nouns in Spanish end with a class marker vowel roughly corresponding to masculine or feminine gender (cf. Harris, 1991). Thus, sabana ‘savanna’, for example, consists of the stem /saban/ plus the class marker /-a/. These nouns exhibit default penultimate stress; idiosyncratic (lexical) antepenultimate stress in words like sábana ‘sheet’ is discussed below. Some nouns, like animál ‘animal’, do not end in a class marker vowel. In these nouns, final stress is the default, though lexical penultimate stress occurs in words like caníbal ‘cannibal’.

It is widely accepted in current analyses of Spanish that the fact that words like animál have default final stress rather than penultimate stress is not due to the fact that these words end in a consonant. Virtually all plural nouns in Spanish end in /-a/, including words like animáles ‘animals’ and sábanas ‘sheets’. Plural nouns exhibit default penultimate stress despite the fact that they end in a consonant. Verb forms similarly exhibit default penultimate stress whether or not they end in a consonant; thus penultimate stress in observed in termina ‘s/he finishes’, terminan ‘they finish’ and terminamos ‘we finish’. The default final stress of animál and other nouns without class markers is not due to phonological factors (i.e. the presence of a word-final consonant), but to morphological structure. Stress is attracted to the end of noun stems, and this overrides the tendency for stress to be nonfinal within a word.

Taking morphological structure into account, then, stress ordinarily falls on the penultimate syllable of nouns with class markers and on the final syllable of nouns without class markers. Other stress patterns are conditioned by specific morphemes which can be considered to be marked in the lexicon in some way to indicate their special status with respect to stress assignment, producing the taxonomy of stress patterns shown in (2). The most common pattern of lexical stress, exemplified in (2b, b’), places stress one syllable to the left compared to the default pattern. Sometimes a single word contains two morphemes which individually condition the marked stress pattern. Words like numérico are thus doubly-marked. The root /nume/ conditions antepenultimate stress in número, and the affix /-ic/ conditions antepenultimate stress in forms like granítico ‘granitic’ (cf. granito ‘granite’ with default stress). However, the effects of multiple marked morphemes are not cumulative. Stress in doubly-marked words is shifted just one syllable to the left relative to default stress, as exemplified in (2c).

Interestingly, all doubly-marked nouns in Spanish have class markers, so there is an apparently accidental gap in the taxonomy at (2c’). Finally, a handful of nouns with no class marker exhibit three different patterns of “exceptional” stress, with stress on different syllables of the stem in singular and plural forms, as in (2d’–d”).

A Metrical Account of Spanish Stress

In order to show the advantages of the NMC model of stress, I will first review the metrical account of Spanish stress proposed by Harris (1995a) in “Projection and
edge marking in the computation of stress in Spanish” (henceforth PEM). The rules in (3) summarize key aspects of Harris’ analysis, abstracting away from irrelevant details of the edge-marking theory of metrical constituents (Ldsardi, 1992).

(3) a. Build a left-headed binary foot at the right edge of the metrical grid
b. Build a left-headed binary foot at the right edge of the rightmost specially-marked morpheme
c. All nouns have a class marker, whether or not it surfaces

The effects of these rules are demonstrated in (4). Rule (3a) groups the last two syllables into a left-headed foot and assigns stress to the head. Marked stress is assigned to morphemes which bear a left-displacement diacritic (here, ‘\( \zeta \)’), which triggers rule (3b) in place of (3a). Finally, PEM maintains that nouns which appear not to have a class marker actually do—default penultimate stress is assigned to these forms, and then their class marker is deleted.

(4) 
\[
\begin{array}{c|c|c}
\text{stressed elements} & \text{stres} \text{ssable elements} \\
\hline
\text{\( * \text{-} * \) } & \text{\( * \text{-} * \) } & \text{\( * \text{-} * \) }
\end{array}
\]
\text{\( \text{sabandn-a} \) } \quad \text{\( \text{numeri-o} \) } \quad \text{\( \text{animal-v} \) }

Several aspects of this analysis deserve comment. Although PEM employs a binary constituent to assign stress, no evidence is presented that just those two syllables are related in a special way or function as a constituent. Indeed, other analyses of Spanish stress have computed the location of primary stress by grouping the penultimate and antepenultimate syllables together rather than the final and the penult (e.g. Roca, 1988). In the absence of independent evidence for one set of constituent relations over another, the binary foot is just a convenient instrument from the metrical toolbox for placing stress two or three syllables from the end of a word.

Like many other analyses of Spanish stress (including Contreras, 1977; Den Os & Kager, 1986; Roca, 1990), PEM accounts for marked stress patterns via a special rule invoked by diacritics associated with certain morphemes. As Harris himself has argued, diacritics are phonetically uninterpretable symbols with no intrinsic phonological content, and should be avoided if possible (Harris, 1985; also cf. Inkelas 1994a). The alternative to such diacritics is of course to enrich the underlying phonological representation enough to account for the surface pronunciation. If phonological representations of stress are restricted to metrical constituent structures and privative metrical grids, there’s simply no way to account for lexical stress in Spanish without resorting to diacritics and special rules. This suggests either that standard metrical representations are inadequate, or that diacritics and special rules are necessary components of phonological theory. If the latter is the case, then underlying phonological representations can be dispensed with altogether, because ALL phonological properties could be accounted for via diacritics (Hammond, 1995; Inkelas, 1994a).

PEM maintains that words like animal have an unseen class marker which simplifies stress assignment. This idea apparently goes back to Foley (1965, cited in Contreras, 1977). The effect of these abstract class markers is to regularize the morphological shape of these words, “dumbing down” morphology for the sake of the phonological stress rules. Arguments against these abstract class markers have been made by Contreras (1977), Elman (1979), and Harris (1991; 1992a). More recently, Harris (1995b) argues against invisible class markers on words like primér “first” and algún “some” (which alternate with primero, algún, depending on the syntactic environment). If abstract class markers are not involved in such forms, then the stress rules must be sensitive to whether or not the morphological structure of a word includes a class marker. This is the approach I pursue in the NMC account below.
Finally, PEM offers no account of the gap in (2c'), nor of the stress-shifting words in (2d'–d''). It has been argued that the handful of words in this latter category are extragrammatical exceptions, maintained only by prescriptivist pressure (e.g. Den Os & Kager, 1986; Harris, 1983; Otero, 1986). Harris (1983) notes that only two of these forms are in general use (régimen and carácter), and that régimen and carácteres are frequent in popular usage, suggesting resistance to the stress shift of the standard forms. While it seems certain that these forms have a different status in native competence than do other words with “grammatical” stress patterns, it’s not at all clear that this difference is attributable to fundamentally different principles of lexical representation and phonological processing. If the supposed grammatical and extragrammatical forms are in fact produced by a single mechanism, then the deviant extragrammatical forms illuminate the capabilities of this mechanism. I will return to the status of these deviant forms relative to the grammar of Spanish after presenting an NMC account of lexical stress in Spanish.

Constraints on Nonmetrical Stress

As an alternative to the PEM analysis and other metrical accounts, I suggest that primary stress in Spanish is a matter of prominence rather than meter, and is best analyzed in terms of constraints on the eligibility of vowels to bear stress, rather than rules for grouping syllables into rhythmic constituents. In particular, the End Rule combined with the constraints on stress eligibility in (5) will account for stress in Spanish. Each of these constraints is instantiated as part of the computation of stress eligibility for each syllable.

(5) a. Syllable Weight—Heavy syllables are more eligible than light ones
b. Edge Bias (Word)—Eligibility is lower near the end of the word
c. Edge Bias (Stem)—Eligibility is higher near the end of noun stems
d. Underlying Prominence—Eligibility is lower in vowels which are idiosyncratically unstressed

Syllable weight. The default penultimate stress of Spanish is a classic quantity-insensitive stress system. For now I will confine the discussion primarily to words of the form L…LH, with a single heavy syllable at the end of the word. The reason for considering words with heavy final syllables is that this represents the worst case scenario—the final syllable in Spanish is unstressed, even if it’s heavy. The reason for concentrating on words where the nonfinal syllables are light is that, aside from a few exceptional cases taken up in §3.1.5, lexical antepenultimate stress in Spanish occurs only in words with light penults. Beyond the final and the penult, the weight of syllables farther from the end of the word has no empirical consequences on stress placement, so the weight of these syllables is irrelevant.

Keeping with the assumption that heavy syllables have twice the weight of light syllables, the syllable weight constraints for words like sabanás and animál will be as shown in (6A). In general, the syllable weight constraints render both light and heavy syllables eligible for stress. For convenience, I will use the weight of a light syllable as a reference unit, and specify the strengths of edge bias and underlying prominence constraints in multiples of L. In these reference units, L=1 and H=2.
(6) Syllable Weight And Word Edge Bias

\[
A \cdot \text{Wt} + B \cdot \text{WE} = C \cdot \text{Wt+WE}
\]

Syllable weight (Wt), word edge bias (WE), and the sum of syllable weight and word edge bias (Wt+WE) for a generic form consisting of an arbitrary number of light syllables (L), and ending with a single heavy syllable (H). The word edge bias balances the weight of a heavy final syllable.

**Edge biases.** In Spanish, default penultimate stress demands that stress be retracted from the end of the word.\(^5\) In the NMC framework, this means an edge bias against stress eligibility at the end of a word must be strong enough to render a final heavy syllable ineligible for stress. The smallest bias strong enough to accomplish this is shown in (6B). Because edge biases are gradient, every vowel of the word is affected, with weaker effects farther from the edge. The sum of the word edge bias and syllable weight is shown in (6C); the edge bias on the final syllable of (6B) exactly cancels the weight of the final heavy syllable of (6A), yielding zero eligibility. Since the final

\(^5\)Harris ([, 1983 #12]; [, 1992 #48]; [, 1995 #18]) and Roca ([, 1990 #65]) have argued convincingly that the domain of stress assignment must include the entire word, and not just the stem (contra [Hooper, 1976 #135], cited in [Aske, 1990 #3]; [Otero, 1986 #137]; [Roca, 1988 #21]).

(7) Stem Edge Bias And Underlying Prominence

\[
A \cdot \text{Wt+WE} + SE = \text{Eligibility}
\]

\[
B \cdot \text{Wt+WE} + SE = \text{Eligibility}
\]

\[
C \cdot \text{Wt+WE} + SE + \text{UP} = \text{Eligibility}
\]

\[
D \cdot \text{Wt+WE} + SE + \text{UP} = \text{Eligibility}
\]

Syllable weight (Wt), word edge bias (WE) and other constraints on stress eligibility. Arrows point to rightmost eligible vowel. (A) Stem edge bias (SE) at end of noun stems makes final syllable eligible for stress in nouns with no class marker. (B) SE has no effect on final syllable in nouns with a class marker. (C, D) Negative underlying prominence (UP) produces marked stress in nouns with and without class markers, respectively.

syllable is not eligible for stress, the End Rule will skip over the final syllable and assign stress to the penult.
If nouns are analyzed as stem+CM+PL, where CM (class marker) and PL (plural) are optional, then default final stress in nouns without class markers suggests a bias for stress at the end of noun stems. This noun stem bias is an independent constraint on stress eligibility, over and above the constraint imposed by the word edge bias. We already have a mechanism for increasing the stress eligibility of vowels at the end of a noun stem if edge biases can be positive as well as negative, and can be associated with any relevant morphological constituents. The smallest edge bias which will produce final stress in nouns like animál with no CM is demonstrated in (7A). The End Rule places stress on the rightmost vowel with stress eligibility greater than zero, correctly producing final stress in words like animál. Of course, the noun stem edge bias also applies to words with a CM like sabána, but here it affects the penultimate vowel rather than the final vowel, as illustrated in (7B), so that penultimate stress is correctly assigned.

**Underlying prominence.** Lexical antepenultimate stress in Spanish can be attributed to vowels which repel stress but are otherwise identical to other vowels (cf. Bailey, 1994; Contreras, 1977:16; Harris, 1983). In the analysis of Harris (1983), antepenultimate stress is the result of lexically-marked extrametrical vowels. The second vowel of número, for example, would be marked extrametrical in the lexicon, so the stress rules would skip over it and assign stress to the antepenultimate instead of the penultimate vowel. In a doubly-marked form like numérico, both the stem /numé/ and the suffix /-ico/ have a lexically-marked extrametrical vowel, indicated here with a slash through the extrametrical vowels. The well-known Peripherality Condition (cf. Hayes, 1981) requires extrametrical elements to be peripheral within the relevant domain; nonperipheral extrametrical elements lose their extrametricality. In Harris’ analysis, the Peripherality Condition revokes the extrametricality of the antepenultimate vowel in numérico because it is not the rightmost vowel within the derivational stem. With its extrametricality revoked, this vowel is available to the stress rules. This analysis has subsequently been abandoned, in part because it decouples the domain of peripherality (the derivational stem) from the domain of stress assignment (the phonological word; cf. Den Os & Kager, 1986). I believe the insights underlying this analysis are essentially correct: (1) antepenultimate stress in Spanish results from lexically-marked vowels which resist stress, and (2) the ability of vowels to resist stress assignment depends on their distance from the edge of relevant morphological domains. The analysis ultimately fails because of the all-or-none nature of extrametricality and the Peripherality Condition. These shortcomings can be overcome by replacing lexical extrametricality with a lexically-specified constraint against stress on certain vowels, and by replacing the Peripherality Condition with gradient edge biases.

Within the NMC framework, the simplest account of vowels which idiosyncratically avoid stress is that they are less eligible to bear stress due to an underlying feature, which I’ll call underlying prominence or ‘[UP]’. Stress makes a vowel relatively prominent, and [UP] reflects otherwise unpredictable (lack of) surface prominence. A vowel will be assigned negative underlying prominence, [-UP], just in case it idiosyncratically surfaces without stress in some environment (or [+UP] if it attracts stress, though this is not relevant to the stress patterns at hand). Giving [-UP] a numeric strength, it can simply be added in with other constraints on stress eligibility, lowering the eligibility of a vowel to bear stress. It is natural to assume that [-UP] will be only as strong as necessary to render a vowel ineligible for stress in those environments where it is idiosyncratically unstressed. This is consistent with the general phonological principles of Simplicity and Recoverability (cf. Archangeli & Pulleyblank, 1994), which

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6By “underlying” I mean only that this phonological information is specified in the lexicon.
maintain that lexical entries are as simple as possible, but contain enough phonological information to correctly reproduce appropriate surface forms.

The relevant difference between _números_ and _sabána_ is that the second vowel of the stem /númer/ surfaces without stress in penultimate position, an environment where Spanish generally expects a vowel to be stressed. The idiosyncratic phonological behavior of /númer/ can be represented in an underlying phonological representation by assigning [-UP] to the second vowel. Assigning this vowel just enough [-UP] to render it ineligible for stress will yield antepenultimate stress as illustrated in (7C). Equations deriving the required amount of [UP] are given in Appendix B.1. The difference between _canibál_ and _animal_ is exactly parallel, and the effect of [-UP] in a word with no CM is illustrated in (7D). Again, stress falls on the rightmost vowel with stress eligibility greater than zero.

**Multiple vowels with [-UP]**. Although [-UP] can render a vowel ineligible for stress, having [-UP] is no guarantee that a particular vowel will be stressless. For example, if the [-UP] in the root /nume/ is just strong enough to produce antepenultimate stress in _número_ (as in 7C), then when that same vowel is farther from the end of the word, as in _numérico_, its stress eligibility will be positive, as shown in (8A) (the suffix -ic has its own [-UP] vowel; cf. _granito_, _granítico_). The fact that only the rightmost vowel with [-UP] avoids stress is an automatic result of the gradience of the word edge bias.

The constraints developed so far make a striking claim about the gap in (2c'). Although it appears that all doubly-marked nouns in Spanish have class markers and hence fall into category (2c), we can create a hypothetical doubly-marked noun with no class marker by stripping the CM off the underlying representation for _numérico_. The result is an underlying representation in which the last two vowels have [-UP]. The constraints developed above predict _númeric_, with initial stress, rather than the more intuitive _numéric_, with stress on the second syllable. This is because without a CM the stem vowels are closer to the end of the word, as shown in (8B). Without the CM, stress is on the first syllable; with the CM, the rightmost vowel with positive eligibility is one syllable farther to the right. This is the exceptional stress “shift” observed in (2d'), suggesting that _régimen_ has two [-UP] vowels and fills the gap in (2c').

In terms of [UP], the other “exceptional” stress patterns also fill gaps. As in (9A, B), a very small [-UP] on the last vowel of stems like /caracter/ and /omicron/ will render that vowel ineligible for stress in singular forms, when it’s word-final. In plural forms that same vowel is farther from the end of the word, has higher eligibility and can bear stress, as shown in (9C, D). Again, vowels are assigned just enough [-UP] to render them ineligible for stress in those forms where they are idiosyncratically unstressed.
The amount of underlying prominence needed to make a final vowel ineligible in a word without a class marker (A, B) will not make the same vowel ineligible in penultimate position, e.g. when followed by a class marker (C, D). **Wt**=syllable weight, **WE**=word edge bias, **SE**=stem edge bias, **[UP]**=underlying prominence.

It might be charged that in accounting for these deviant stress patterns I’ve failed to account for their deviance. PEM proposes a set of rules and diacritics which produce all and only the fully grammatical forms and does not produce the exceptional stress-shifting forms. The deviance of the exceptional forms is therefore accounted for by the fact that the grammar doesn’t generate them. In contrast, the NMC account produces the exceptional stress-shifting stress patterns by simply employing underlying prominence, a theoretical device which is also needed for regular, fully grammatical forms.

Superficially, this appears to suggest that the stress-shifting forms should be just as “normal” in Spanish as the productive stress patterns of (2a–c).

Actually, the difference between the two accounts of the deviant forms is smaller than it might appear. I develop a set of constraints on prominence for default (non lexically-governed) stress patterns, then identify the particular amounts of underlying prominence that will account for all and only the fully grammatical lexical stress patterns. I go on to identify additional configurations of underlying prominence which will account for the stress-shifting forms of (2d). PEM develops a set of rules for the canonical stress patterns, then proposes special rules and diacritics to produce all and only the fully grammatical lexical stress patterns. In principle, additional rules and diacritics could be formulated to produce the deviant forms as well (cf. the appendix of Harris, 1983). PEM gives a certain set of rules and diacritics as constituting the core native competence of Spanish speakers. I give an account of this same native competence in terms of a certain set of underlying prominence values. The real difference between the two approaches is one of rules versus representations. For PEM the fully grammatical forms are distinguished from the deviant forms by the rules that generate them. For the NMC account, the fully grammatical forms are distinguished from the deviant forms by differences in the underlying phonological representations.

The analysis of Spanish presented above produces a new taxonomy of stress patterns, shown in (10). The “exceptional” stress patterns occupy positions which would otherwise be empty, (10b, d’ and e’). The gaps in (10b, d) are structural, inherent in the way [UP] interacts with edge biases—weak [-UP] can produce a distinct stress pattern
(10) New Taxonomy Of Spanish Nouns

<table>
<thead>
<tr>
<th>Underlying prominence</th>
<th>Class Marker (singular/plural)</th>
<th>No Class Marker (singular/plural)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>a. sabána/sabanas</td>
<td>a’. animádi/animádles</td>
</tr>
<tr>
<td>Singly-marked:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak stem-final</td>
<td>b. —</td>
<td>b’. carácter/caractéres</td>
</tr>
<tr>
<td>Strong stem-final</td>
<td>c. número/números</td>
<td>c’. canibál/canibales</td>
</tr>
<tr>
<td>Doubly-marked:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak stem-final</td>
<td>d. —</td>
<td>d’. ómicron/ómicrónes</td>
</tr>
<tr>
<td>Strong stem-final</td>
<td>e. numérico/numéricos</td>
<td>e’. régimen/regímenes</td>
</tr>
</tbody>
</table>

only in nouns with no CM, where the distance between vowels and the end of the word differs in singular and plural forms. In other words, there are no words of type (10b) or (10d) because a word with a class marker and a stem-final vowel with weak [-UP] would exhibit penultimate stress. Such a word would be indistinguishable from a similar word with no [-UP] on the stem-final vowel. The principles of simplicity and recoverability suggest that a word with this stress pattern should have a maximally simple underlying lexical representation, omitting information about stress (i.e. the feature [UP]).

**Discussion and Conclusion**

The NMC account of Spanish maintains that stress is constrained by syllable weight, proximity to morphological edges, and underlying prominence. Where PEM relies on lexical diacritics to invoke special rules for marked stress, the NMC analysis associates [-UP] with vowels which repel stress—since [-UP] is a direct reflection of otherwise unpredictable surface prominence, it’s a phonological feature, not a diacritic for manipulating rules of the grammar. This characterization of [UP] blurs the distinction between representations and constraints, but retains underlying representations as the locus of unpredictable phonological information (contra Hammond, 1995; also see Bird & Ellison, 1993 on unifying rules and representations).

The dependence of PEM on abstract class markers is avoided in the NMC analysis by making stress assignment directly sensitive to morphological structure, with constraints on the eligibility of vowels to bear stress depending on their proximity to relevant edges. The gradience of edge biases interacts with [UP] to account for stress in doubly-marked forms in which vowels are stressed in some environments even though they repel stress in other environments.

The stress-shifting words of Spanish are also accounted for in the NMC model by interactions between gradient edge biases and [UP]. It’s clear that Spanish speakers know the stress-shifting words of Spanish are deviant or unusual (the deviance of these forms is discussed in more detail in §3.1.2). According to Harris (1983:132), “we should not modify an otherwise well-motivated linguistic description solely to accommodate these aberrant cases.” However, the constraints on stress eligibility in (5) were motivated by the nonexceptional forms in (2a–c), and we have an otherwise well-motivated description that accommodates the aberrant cases without modification.

If the difference between stress-shifting forms and words with more productive stress patterns is not explained by arbitrarily invoking separate mechanisms for them, at the very least we must ensure that there is enough information in the lexical entries of the exceptional stress-shifting forms to distinguish them from other words. Certainly this is true of the underlying form proposed in the NMC account of régimen, which involves two vowels with [-UP] in a single morpheme; none of the non-deviant words of Spanish have this dual configuration of [-UP]. Analyzing words like régimen, Washington, and ómicron as having two vowels with [-UP] both accounts for the observed stress patterns and marks them as different from other Spanish nouns. In addition, it’s likely that
speakers are sensitive to a shift in stress between singular and plural forms of a noun, and this produces an effect over and above effects induced by deviant underlying representations. Knowledge of this nature relates surface forms of inflectionally related words. The model of stress developed in the present work does not provide a mechanism for representing such knowledge directly, though I see no obstacle to adding constraints on stress which relate stress eligibility in one form to the surface stress pattern of related forms.7

3.1.2. Extragrammaticality

The grammatical status of régimen and the handful of other stress-shifting words in Spanish has been the subject of some debate. Harris (1983 and elsewhere) maintains that these words are not part of the internalized language system acquired by Spanish speakers, but are part of the extensive flotsam and jetsam surrounding the native competence of speakers. In other words, one mechanism is responsible for core linguistic competence, and some separate peripheral mechanism accounts for deviant exceptions. In order to focus on the core mechanism, Harris (1992b:9) sets aside the exceptional stress-shifting words—they “are accorded the benign neglect they deserve.” In contrast, Roca (1988, 1990) accepts them as legitimate objects of study and analyzes them along with the less exceptional stress patterns of Spanish.

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7McCarthy ([, 1995 #200]) proposes just such a constraint within Optimality Theory. McCarthy’s HEAD-MAX constraint requires the primary stress to fall on corresponding vowels in related words. I note that constraints between related surface forms constitute a departure from the assumption that transderivational relationships are to be accounted for via cyclic rule application. According to Halle & Vergnaud ([, 1987 #11:204]), cyclicity is “one of the most basic principles of generative phonology.”

Accepting the conclusion that these stress-shifting forms really are deviant in some sense, there are at least two important questions to resolve. First, are these words generated by the same phonological mechanism which is responsible for words with less deviant stress patterns, or is there reason to believe a separate mechanism is involved in producing the stress-shifting forms? Second, are these forms really worthy of neglect, or do they tell us something about the nature of the language faculty? I will address some comments to this second question first, and then discuss evidence that the stress-shifting forms really are deviant and how this evidence bears on whether one or two mechanisms are involved.

Knowledge of Language

Productivity—the ability of people to produce and understand novel words and phrases—is a remarkable aspect of language. Much, perhaps most, work in linguistics is aimed at identifying the principles underlying the capacity of language users to apply knowledge of their language productively. It is sometimes tempting to focus on apparent rule-based patterns in language, and dismiss isolated exceptions to those patterns (like the stress-shifting words of Spanish) as nuisance noise. However, such an approach can be misleading, as noted in the quote from Sharon Inkelas at the beginning of this chapter. The fact is, there is more to language than rule-based productivity. Pierrehumbert (1994), for example, discusses a number of linguistic patterns which have been described by rules, and shows that the rules represent statistical tendencies or prototypical behaviors with significant variability. It goes without saying that variability is observable only if one examines all the data and not just the data which conform to the apparent rules. Pierrehumbert argues that variability and exceptions are not isolated, peripheral properties of language. Rather, “language exhibits variability at all levels of representation” (Pierrehumbert, , p. 233). As Pierrehumbert argues, if variation is
intrinsic to language, then linguistic theory must account not just for the gross productive patterns of language, but for deviations from those patterns as well. A generative grammar “purports to depict exactly what one knows when one knows a language” (Chomsky, 1986:24). Knowledge of a particular language includes knowledge of how the rules of that language accommodate exceptions. For many speakers of Spanish, knowledge of language includes a small number of stress-shifting words, and any grammar which does not account for these words is not a grammar of the language these people know. Exceptions and variability are not just nuisance noise, but represent valuable data which should inform our theory of language.

**Single vs. Dual Mechanisms**

Accepting that the stress-shifting words of Spanish might shed light on the underlying language faculty, there is still the possibility that these forms involve a separate subsystem from the one which produces the other, productive stress patterns. I will discuss three arguments put forth in support of the extragrammatical status of the stress-shifting words: (1) many speakers regularize the stress of these words to conform with less exceptional forms; (2) speakers reject similar nonce forms as non-Spanish; (3) speakers may exhibit inflectional uncertainty about how to form plurals from singular forms like *Júpiter* ‘Jupiter’. While these observations establish the deviance of the stress-shifting forms, it is not at all clear that a separate mechanism is needed to account for them. Finally, I will discuss evidence from language acquisition and comment on the relationship between stress and other aspects of phonology.

**Regularization.** Harris (1983) notes that though *régimen* is a common word, it is often regularized in popular usage to *regimen*, so that stress is on the same syllable of the stem in singular and plural forms (cf. plural *regímenes*). This regularization results in a word with the same stress pattern as that observed in *caníbal/canibales*. Similarly, *caractéres* is often regularized to *carácteres* (cf. singular *carácter*). In order to put these regularizations in context, it may be helpful to consider historical regularizations of past tense forms in English. The history of English provides many examples of irregular past tense forms becoming regularized. Historically irregular verbs which now take regular past tense include: *glide, gripe, spew*, and *writhe*, which were formerly of the *write/wrote* class; regular *chew, brew, rue, reek, seethe, crowd, shave, sprout*, and *suck* were formerly of the same class as *creep/crept*; regular *climb, help, bark, burn, braid, carve, starve, mourn, spurn, yield, yell, yelp, melt, swallow, and swell* were formerly of the same class as *sing/sang* (Pyles, 1964). As Pyles notes:

> Throughout the history of English the strong verbs, always a minority, have fought a losing battle, having either joined the ranks of the weak verbs or been lost altogether.  

Pyles (1964:194)

Presumably the historical changes mentioned above involved transitional stages with both regular and irregular forms of a verb occurring synchronically. Indeed, a number of verbs in contemporary English exhibit variability between regular and irregular past tense forms, including *dived/dove, dreamed/dreamt, crowded/crew, hanged/hung*. All of these could plausibly be described as showing a tendency to regularize in popular usage. Does a tendency to regularize justify the conclusion that the irregular forms in question are extragrammatical exceptions, processed by a separate mechanism than that responsible for the regular forms? Apparently not (pace Marcus et al., 1992). Historical change occurs in both directions, and formerly regular words sometimes take on irregular patterns. English *hide, dig, and stick*, for example, were formerly regular but now exhibit the irregular past tense forms *hid, dug, and stuck* (Pyles, 1964:196-199). Whatever is going on is more complicated than just saying extragrammatical irregular forms tend to get sucked into the grammar. Moreover, Hare & Elman (to appear) describe a connectionist model of change over time in English past
tense forms. This model employs a single mechanism for both regular and irregular past
tense forms, and the success of the model in accounting for at least general patterns of 
change in the history of English suggests that regularization can be accounted for without 
appealing to separate mechanisms for regular and irregular forms.

Regularization certainly reveals something about the relationship between 
régimen and the rest of the Spanish lexicon, but the fact remains that many speakers 
retain the standard forms régimen/regímenes and carácter/caractéres. Whether these 
forms are the result of prescriptive pressure or not, there is surely some state of 
mind/brain for these speakers which represents the phonological structure of these words 
and their stress patterns, and it falls within the scope of linguistic theory to give an 
account of the relevant knowledge structures.

Rejection. Speakers will reject nonce forms with the same phonological shape as 
régimen as being ungrammatical or non-Spanish. This is indeed noteworthy, but it is not 
clear that it justifies the conclusion that some special mimicry mechanism outside the 
grammar of Spanish is responsible for actual words like régimen. As Janet Pierrehumbert 
has pointed out, “judgments of well-formedness do not provide a direct tap into linguistic 
competence,” (Pierrehumbert, 1994:252). For comparison with the Spanish data, 
consider exceptional syllable onsets in English words like vroom and sphere. Accounts 
of English syllable structure generally maintain that /vr/ is not a valid syllable onset in 
English, and /sf/ is likewise either prohibited (e.g. Goldsmith, 1990:142) or at least 
questionable as a syllable onset in English (e.g. Clements & Keyser, 1983:41). One of 
the claims implicit in these analyses is that native speakers intuitively know that typical 
English words do not start with /vr/ or /sf/ clusters. Nevertheless, many English speakers

*(I am grateful to Jim Harris for pointing out the relevance of vroom to the 
discussion of the grammatical status of régimen, etc., in Spanish.)*

(including myself) use a few words like vroom and sphere that violate the proposed 
constraints against these clusters. Evidently, linguistic knowledge is not necessarily 
internally consistent.

Some knowledge structure underlies the use of exceptional phonological forms, 
and that knowledge integrates these words into regular morphological and syntactic 
structures. What is the knowledge structure underlying the phonological form of 
exceptions like vroom and sphere? The simplest hypothesis is that language users simply 
built lexical entries for these forms that include the offending consonant clusters. In 
other words, the lexical representation for vroom is /vr/um/, or perhaps /vr/um/ with 
underlying syllable structure, and the representation for sphere is /sf/er/ or /sf/er/

These lexical entries will certainly be unusual, but they must contain enough information 
to reproduce the target surface forms. Phonological theory doesn’t need a special 
mechanism to account for vroom or sphere, because the machinery independently needed 
for the rest of English is more than enough to accommodate them, given appropriate 
lexical representations. Similarly, the NMC account proposed above for exceptional 
Spanish forms like régimen involves “deviant” lexical entries. We do not need a 
separate, extragrammatical, mechanism. These forms can be accommodated within the 
grammar of Spanish provided that the grammar is robust enough to deal gracefully with 
unusual lexical entries—as in the proposed NMC account.

Although we do not need a separate processing mechanism for these kinds of 
lexical exceptions, we do need a theory of where grammaticality judgments come from 
and why they are sometimes inconsistent with actual linguistic competence. I speculate 
that such a theory could be based on the token and type frequency of phonological 
structures (and combinations of structures) in the lexicon, with judgments of 
“grammaticality” actually reflecting something on the order of typicality. The
relationship between grammaticality judgments and linguistic competence is largely
tangential to the focus of the present work, and will not be pursued further here.

**Inflectional uncertainty.** The word *Júpiter* provides another interesting example
in Spanish. Harris observes that Spanish speakers cannot produce a plural form for this
word that they find acceptable (e.g. to deny the presence of two Jupiters in our solar
system). Harris takes this as evidence that *Júpiter* is not fully part of the language, but is
in some sense extragrammatical. In addition, Harris extrapolates this conclusion to
phonologically similar words like *régimen*. Again, it is not clear that Harris’ conclusions
follow from the data. A recent experiment conducted in the University of Minnesota
Experimental Linguistics Laboratory required subjects to produce past tense forms for
irregular English verbs. One of the practice trials involved the verb *sling*. A large
proportion of the English-speaking undergraduate students participating in the
experiment could not produce a past tense for *sling* that they found acceptable. Some
subjects hesitated, then stated that they didn’t know what the past tense was. Other
subjects tried and rejected one or two possibilities (typically *sling* or *slang*) before giving
up. This seems to be similar to the difficulty Harris reports for Spanish speakers in
finding a plural for *Júpiter*. If we accept Harris’ argument regarding *Júpiter* and *régimen*
in Spanish, and employ the same line of reasoning to *sling* in English, we must conclude
that *sling* is an extragrammatical exception in English, and moreover, that similar words
like *sing* are also extragrammatical. At this point it appears that what Harris means by
extragrammatical is merely irregular.

The relationship between regular and irregular morphology in English has been
the subject of much debate (e.g. Hare & Elman, to appear; Marcus et al., 1992; Pinker &
Prince, 1988; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986; Stemberger,
1994, 1995). However, this debate has focused on whether the regular and irregular
forms are best accounted for by a single mechanism or whether separate mechanisms are
responsible for regular and irregular forms. I have not seen claims in the literature that
the irregular verbs of English are not fully included in the linguistic competence of native
speakers (i.e. are extragrammatical), nor that they are “worthy of benign neglect” as
Harris has proposed for the phonologically irregular stress-shifting forms in Spanish.

**Evidence from acquisition.** Another way to evaluate the status of the exceptional
stress pattern of *régimen* is to evaluate the difficulty speakers have in learning novel
forms with that patterns. Hochberg (1988) studied the acquisition of various Spanish
stress patterns by examining errors in spontaneous and imitated speech in preschool-aged
children. Hochberg’s study distinguished between regular, irregular, and “prohibited”
patterns of stress in noun forms. These three categories were based on Harris’ distinction
between forms produced by the main stress rule (e.g. *cuchara* ‘spoon’, *tenedor* ‘fork’),
those which require lexical diacritics (e.g. *teléfono* ‘telephone’), and those which are
claimed to be extragrammatical. This latter category included forms like *cátapana*
which are completely unattested, as well as forms like *pánaquil* and *sósenga* which are
similar in syllable structure and stress placement to words like *régimen* and the place
name Frómista —although attested, these stress patterns are recognized by Spanish
speakers as deviant and are claimed by Harris to be extragrammatical.

Hochberg’s imitation task included nonce words with six different word shapes,
exemplified by the forms *gaga*, *bochaca*, *sosenga*, *cátapana*, *guifor*, and *panaquil*.
Children were asked to imitate the nonce words with various stress patterns, e.g. irregular
stress *bóchaca* or *bochác*; or regular stress, *bocháca*. Hochberg recorded the number of
errors children made in imitating the nonce forms, and compared the number of errors for
regular, irregular and prohibited stress patterns. Children made significantly more errors
overall in trying to imitate irregular than regular stress patterns. This is consistent with
theoretical analyses which distinguish between patterns produced by a basic rule (the
regular patterns) and those involving some sort of lexical exception to the basic rule (the
irregulars). If the “prohibited” stress patterns really have a different status relative to the
grammar of Spanish than the merely irregular stress patterns do, we might expect them to
be even more difficult for children to imitate. This expectation is not born out by the
results of Hochberg’s study. The data for the three word forms which tested prohibited as
well as irregular and regular stress patterns are summarized in (11).

Children were actually slightly MORE likely to make errors on the irregular stress
patterns than they were to make errors on the supposedly prohibited patterns. The overall
rate of errors on the irregular stress patterns of (11) is 66%, while the rate of errors for the
prohibited patterns is only 56%. In contrast to both irregular and prohibited patterns, the
error rate on regular stress patterns was 28%. In short, this study did not find that the
prohibited patterns of stress were more difficult for children to mimic than the merely
irregular stress patterns were.

Logically, irregular and prohibited forms might be processed by a single mimicry
mechanism or by two different mechanisms. If they are processed by a single
mechanism, it might either be the extragrammatical device which is hypothesized to
account for forms like régimen, or it might be the grammar itself and the facilities it
provides for deviations from regular patterns. If the irregular and prohibited forms are
processed by different mechanisms, then those two mechanisms apparently mimic novel
forms within their respective domains of responsibility with equal facility. However, it is
not clear why or how the merely irregular forms would be delegated to the grammar
rather than the extragrammatical mimicry device. It also would be a remarkable
coincidence that the two mechanisms are equally proficient.

If the irregular and prohibited nonce forms are both processed by an
extragrammatical mimicry device, then the results of Hochberg’s experiment suggest this
device is less proficient at mimicking novel forms compared to the efficiency of the
grammar at mimicking novel forms which conform to the regular patterns. Aside from
the relative efficiency of the two mechanisms hypothesized, the results suggest that
irregular and prohibited forms are both different from regular stress patterns. However,
there must be some connection between mimicking novel forms and acquiring new
words. Actual words with irregular stress must be integrated into the grammar in order to
account for productive use of derivational and inflectional affixes which condition
irregular stress (e.g. the /-ic/ of grántico and the /-bal/ of terminábamos). If the mimicry
of both irregular and prohibited patterns involves an extragrammatical device, it remains
a mystery why words with irregular patterns become integrated into the grammar while
words with prohibited patterns do not (if they did they would not be extragrammatical as
Harris maintains they are).

Finally, nonce forms may be processed through the grammar itself. In this case,
the results of the Hochberg study distinguish regular patterns from both irregular and
prohibited stress patterns. However, nonce forms with irregular and prohibited stress
patterns were not so clearly distinguished from each other. This suggests that the
deviance of the prohibited stress patterns (as measured by grammaticality judgments of
the sort cited by Harris and discussed above) cannot be explained in terms of inherent
incompatibility with the knowledge embodied by the grammar. Again, this casts doubt

<table>
<thead>
<tr>
<th>Stimulus Type (example)</th>
<th>Stress (distance from end of word)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV.CV.CV.CV (catapana)</td>
<td>46 (p)</td>
<td>130</td>
</tr>
<tr>
<td>CV.CV.CV.CV (sosenga)</td>
<td>77 (p)</td>
<td>245</td>
</tr>
<tr>
<td>CV.CV.CV.CV (panaquil)</td>
<td>34 (p)</td>
<td>245</td>
</tr>
</tbody>
</table>

Percent error on imitations in Hochberg study, by stress location and stimulus type.
(r) = regular, (i) = irregular, (p) = prohibited. N = number of imitations elicited for
each stress variant in the row.
on the sharp distinction Harris draws between irregular forms and supposedly extragrammatical forms exhibiting supposedly prohibited patterns of stress.

Other aspects of phonology. Simply categorizing words like régimen as extragrammatical because of their exceptional stress pattern makes it difficult to account for other aspects of their phonological form. Although these words are phonologically deviant (in that they have exceptional stress patterns), they are only SLIGHTLY deviant. Foreign place names with antepenultimate stress such as Washington, Cölchester, etc., are freely adopted (Roca, 1990) by many speakers of Spanish. These names are similar to régimen in relevant respects.9 As Roca points out, the segmental phonology of these names is often nativized (e.g. [gwásinton] “Washington”), suggesting a link with the phonological system of Spanish which would be totally unexpected if they were phonologically “extragrammatical”. If words like régimen and Washington are extragrammatical at some level of representation, it remains to be worked out how and when that extragrammatical level interfaces with the grammar of Spanish.

3.1.3. Nonlexical Stress in Spanish Verb Stems

In Spanish verbs, as in Spanish nouns, canonical stress is penultimate, and deviations from the canonical pattern are conditioned by specific morphemes (Harris, 1987; Harris, 1989). However, deviations from penultimate stress in verbs are conditioned only by inflectional suffixes, and never by particular verb stems. Especially interesting is the fact that noun stems which induce antepenultimate stress in noun and adjectival forms do not induce antepenultimate stress in verb forms. In other words, stems which condition lexical stress patterns in nouns do not condition lexical stress in verbs. Consider the examples in (12), where vowels which evidently avoid stress in noun forms are underlined.

(12)  

<table>
<thead>
<tr>
<th>Noun</th>
<th>Verb</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>número</td>
<td>numgro</td>
<td>'number'</td>
</tr>
<tr>
<td>término</td>
<td>termjo</td>
<td>'end'</td>
</tr>
<tr>
<td>platja</td>
<td>platja</td>
<td>'chat'</td>
</tr>
<tr>
<td>limite</td>
<td>limite</td>
<td>'border'</td>
</tr>
<tr>
<td>participe</td>
<td>participe</td>
<td>'participant'</td>
</tr>
</tbody>
</table>

In §3.1.1, noun forms with antepenultimate stress, like número, were accounted for by associating negative underlying prominence with the penultimate vowel. This vowel is idiosyncratically unstressed in an environment where stress is normally expected. If the second vowel of the stem /nume/ has [-UP]—as it must have to account for antepenultimate stress in the noun número—then why doesn’t that [-UP] prevent that same vowel from being stressed when it appears in the verb form número? One straightforward way of accounting for this behavior is to simply list which morphological units are allowed to induce marked stress patterns and which are not. As Harris notes, “In nouns, adjectives, and adverbs, both stems and affixes can be triggers” of antepenultimate stress (Harris, 1995a:4). In contrast, “in verbs only certain inflectional affixes play this role.” Of course, this itemization merely stipulates the facts. Alternatively, we might hypothesize that while nouns undergo a single round of stress...
assignment, verbs undergo two rounds in such a way that the second round completely masks the first round, and the lexical idiosyncrasy of the stem has no effect on stress placement in the second round (cf. Halle, Harris & Vergnaud, 1991). As Harris observes, this two-round approach invokes abstract intermediate representations which have no empirical consequences.

The key insight behind both the itemization and the two-round approaches above is that even when the segmental material of verbs and nouns is identical, as in the examples in (12), the morphological structure of verbs and nouns is different, and stress is sensitive to this difference. In the NMC framework, edge biases link morphological structure and stress. In Spanish verbs, stress never falls more than one syllable inside a verb stem; in other words, stress is attracted to the right edge of verb stems. This attraction is strong enough to overcome the [-UP] associated with the last vowel of stems like /numer/ when they occur in verb forms. Evidently there is a positive edge bias associated with the right edge of verb stems. In order to overcome the [-UP] of stems like /numer/, the verb edge bias must be at least as strong as +0.5.

The constraints on stress eligibility in the noun número and the verb número are demonstrated in (13). In the noun form, the [-UP] renders the penult ineligible for stress, so stress falls on the antepenult. In the corresponding verb form built from the same stem, the verb edge bias overpowers the [-UP] so that the penult is eligible for stress. This NMC account of stress in corresponding noun and verb forms accounts for the facts in terms of independently motivated elements of the theory (underlying prominence and edge biases), without simply stipulating the facts or positing intermediate representations with no empirical consequences.

(13) Verb Stem Edge Bias

A  Wt+WE +  NSE +  [UP]  =  Eligibility

B  Wt+WE +  VSE +  [UP]  =  Eligibility

(A) [-UP] in nouns like número overcomes edge bias at the end of noun stems to induce antepenultimate stress. (B) The same [-UP] is not sufficient to overcome a stronger edge bias at the end of verb stems, so the penult is eligible for stress despite the [UP], producing penultimate stress in verbs like número. Wt = syllable weight, WE = word edge bias, NSE = verb stem edge bias, VSE = verb stem edge bias, [UP] = underlying prominence. Arrows point to rightmost eligible vowel.

3.1.4. Lexical Stress in Spanish Verbs

In Spanish verbs, default stress is on the penultimate syllable, just as it is in nouns, producing forms like cocina ‘she cooks’ and cocinamos ‘we cook’. A thorough discussion of Spanish verb morphology and stress can be found in Harris (1987). Some inflectional suffixes condition antepenultimate stress, as exemplified by the first person plural forms in the second column of (14). As seen in the singular forms in the first column of (14), however, these inflectional suffixes do not really condition antepenultimate stress, per se. The underlined vowels evidently resist stress, producing antepenultimate stress only when they occur in penultimate position. I will analyze these
vowels as having just enough [-UP] to avoid stress in penultimate position. When an inflectional vowel with [-UP] occurs in final position, regular penultimate stress occurs; only when the [-UP] vowel occurs in penultimate position does stress get retracted onto the antepenultimate syllable.

<table>
<thead>
<tr>
<th>1/3sg</th>
<th>1pl</th>
<th>Tense/mood</th>
</tr>
</thead>
<tbody>
<tr>
<td>cocinábą</td>
<td>cocinábamos</td>
<td>imperfect</td>
</tr>
<tr>
<td>cocinarą</td>
<td>cocinaramos</td>
<td>conditional</td>
</tr>
<tr>
<td>cocinág</td>
<td>cocináamos</td>
<td>past subjunctive I</td>
</tr>
<tr>
<td>cocinás</td>
<td>cocinámos</td>
<td>past subjunctive II</td>
</tr>
</tbody>
</table>

The verbal suffixes which induce antepenultimate stress are much like the noun stems and suffixes which condition antepenultimate stress, but the verbal suffixes occur in a different morphological environment, with a different configuration of edge biases. Verbal inflections lie outside the verb stem, so they are subject to the negative bias at the right edge of the word but are not subject to the positive bias at the right edge of the verb stem. This affects the strength of the underlying prominence. Outside a verb stem, the weakest [-UP] which will produce antepenultimate stress is about –0.26, which is somewhat weaker than the [-UP] needed to induce antepenultimate stress in noun forms like número. To demonstrate the assignment of antepenultimate stress in Spanish verbs, the constraints on stress eligibility for numerábamos and numerábamos are shown in (15).

(15) Unstressed Penults in Verb Inflections

<table>
<thead>
<tr>
<th>A</th>
<th>Wt+WE</th>
<th>+</th>
<th>VSE</th>
<th>+</th>
<th>[UP]</th>
<th>=</th>
<th>Eligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[L L L H]</td>
<td></td>
<td>[X X] X</td>
<td></td>
<td>[[X X] X X]</td>
<td></td>
<td>![Diagram A]</td>
</tr>
<tr>
<td>B</td>
<td>Wt+WE</td>
<td>+</td>
<td>VSE</td>
<td>+</td>
<td>[UP]</td>
<td>=</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[L L L H]</td>
<td></td>
<td>[X X] X</td>
<td></td>
<td>[[X X] X X]</td>
<td></td>
<td>![Diagram B]</td>
</tr>
<tr>
<td>C</td>
<td>Wt+WE</td>
<td>+</td>
<td>VSE</td>
<td>+</td>
<td>[UP]</td>
<td>=</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[L L L H]</td>
<td></td>
<td>[X X] X</td>
<td></td>
<td>[[X X] X X]</td>
<td></td>
<td>![Diagram C]</td>
</tr>
</tbody>
</table>

(A) In unmarked inflections, stress falls on the penultimate syllable as in numerábamos. (B) In final position, [-UP] only further reduces the eligibility of the penultimate syllable, so penultimate stress is observed in words like numeraba. (C) In penultimate position, [-UP] renders the penult ineligible, so stress falls on the antepenultimate syllable in words like numerábamos. Wt=syllable weight, WE=word edge bias, VSE=verb stem edge bias, [UP]=underlying prominence.

There are also some verb inflections which condition final stress instead of the default penultimate stress, as shown in (16) where vowels which attract stress are printed in an outline font. These inflections have vowels which idiosyncratically attract stress—this is just the reverse of the [-UP] vowels, which repel stress, and the obvious account of the inflections which condition final stress is to assign [+UP] to their last vowel. This
must be strong enough to overcome the negative bias at the end of the word, rendering the vowels eligible to bear stress. The weakest [+UP] which will accomplish this is +1.25. The constraints on stress eligibility for merecí and merecímos are demonstrated in (17).

(16) merecer ‘to deserve’

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Final</td>
<td>Penultimate</td>
<td>Tense/Number</td>
<td></td>
</tr>
<tr>
<td>merec</td>
<td>merec</td>
<td>m</td>
<td>preterit 1sg, 1pl</td>
</tr>
<tr>
<td>merec</td>
<td>merec</td>
<td>m</td>
<td>preterit 3sg</td>
</tr>
<tr>
<td>merecer</td>
<td>merecer</td>
<td>m</td>
<td>future 1sg, 1pl</td>
</tr>
<tr>
<td>merecer</td>
<td>merecer</td>
<td>m</td>
<td>future 3sg</td>
</tr>
</tbody>
</table>

3.1.5. Violations of Quantity-Sensitivity in Spanish

Stress theory distinguishes between quantity-sensitive stress systems, in which stress placement is sensitive to syllable structure, and quantity-insensitive stress systems, in which stress placement is indifferent to the internal structure of the syllable. Whether this dichotomy is attributed to parametric variation or language-specific rules, the traditional view holds that within a particular stress system, well-formed metrical structure either does or does not depend on the internal structure of the syllable. Spanish poses something of a challenge, however, for a strict dichotomy between quantity-sensitive and quantity-insensitive stress assignment, because the stress patterns of Spanish support arguments both for and against a quantity-sensitive analysis.

10I assume that two stress eligibility values must differ by some minimal amount in order to be distinguishable; here I arbitrarily adopt the value 0.25 as the minimal difference required to distinguish a positive eligibility from 0.

11A version of the following discussion appeared in Bailey (1994).

(17) Final Stress in Verb Inflections

A Wt+WE + VSE = Eligibility

B Wt+WE + VSE + [UP] = Eligibility

C Wt+WE + VSE + [UP] = Eligibility

(A) With no [UP], stress is penultimate in words like merecó. (B) In final position, [+UP] makes the final syllable eligible for stress in words like merecó. (C) In penultimate position, the same [+UP] just increases the eligibility of the penult in words like merecímos. Wt=syllable weight, WE=word edge bias, VSE=verb stem edge bias, [UP]=underlying prominence.

Lexical stress in Spanish has typically been analyzed as involving memorized exceptions, special rules, and exemption from rule application for specially-marked lexical items (e.g. Halle et al., 1991; Harris, 1995a; Roca, 1990; and many others). Elaborating on the account of lexical stress in Spanish developed above, I will show how the apparent contradictions of Spanish quantity-sensitivity are resolved when syllable weight and underlying prominence are constraints with numerical strengths. In the
proposed account, apparent counter-examples to quantity-sensitivity are seen to result from exceptionally strong underlying prominence; this renders certain lexical entries phonologically unusual, but avoids diacritics and special rules.

**Syllable weight.** As discussed above, in most Spanish words the default stress pattern places stress on the penultimate syllable. Intuitively, this is just a matter of retracting stress one syllable from the end of the word, and no knowledge about the internal structure of syllables is required for this computation. This is a classic quantity-insensitive stress pattern. Nevertheless, several types of evidence, summarized in (18), suggest that stress assignment in Spanish is actually quantity-sensitive.

(18) Evidence for Quantity-Sensitivity in Spanish

a. dearth of words with antepenultimate stress and heavy penults

b. rejection of nonce forms like *a.tá.pam.ba, *ti.nan.bo, *cá.nas.ta, *te.lé.fio.no versus possible a.tá.pa.ma, etc. (Harris, 1983:11, 1992b:17, and elsewhere)

c. hypercorrection in /s/-deletion dialects, e.g. hi.po.po.ta.mo ‘hippopotamus’:

   hi[sl].po.pó.ta.mo, hi.po[sl].pó.ta.mo, hi.po.pó[sl].ta.mo, but *hi.po.pó.ta[sl].mo

   (Núñez Cedeño, 1986)

Specifically, (18a–c) all suggest that antepenultimate stress is possible in Spanish only if the penultimate syllable is light. Antepenultimate stress occurs almost exclusively in words with light penults, and hardly ever in words with heavy penults (exceptions like Fró.nis.ta and Wá.shing.ton are discussed below). This observation has been discussed in many works on Spanish stress, including the works cited above. Furthermore, Harris and others have observed that native speakers strongly reject nonce forms with unstressed heavy penults. Minimally different forms with light penults are quite acceptable.

Finally, Núñez Cedeño (1986) describes dialects of Spanish which systematically delete /s/ in syllable-final position. In hypercorrections, an extraneous /s/ may show up in virtually any syllable, except hypercorrections never insert an /s/ in an unstressed penult.

Insertion of /s/ on this syllable would produce a word with an unstressed heavy penult, a configuration which is apparently avoided by Spanish speakers. We are led to the conclusion that syllable structure and stress interact, i.e. Spanish stress is quantity-sensitive.

**Evidence for Quantity-Insensitivity**

According to the traditional view of metrical theory, quantity-sensitivity is an either/or proposition. If stress assignment in Spanish is quantity-sensitive, antepenultimate stress should occur only in words with light penultimate syllables. Any word with antepenultimate stress and a HEAVY penult would violate a rule of the grammar. In fact, Spanish has a number of such “violations”, exemplified in (19).

(19) Problems for Quantity-Sensitivity


b. lim.pie.mos, en.ví.de.mos, a.ca.rí.cie.mos, …

   ‘clean, envy, caress’ (1pl pres subj, some dialects) (Harris, 1995a)

Among nouns, the traditional place name Fró.nis.ta and numerous foreign words clearly exemplify antepenultimate stress in the face of heavy penults. These forms simply cannot be accommodated within a quantity-sensitive analysis of the traditional sort. Some would argue that these forms do not matter; as Harris observes,

   unshifted stress in loan words tells us absolutely nothing about the rules internalized by borrowers; all we learn is that mimicry of foreign stress patterns is possible. (Harris, 1992b:17-8)

At issue here is whether language really can be divided into two kinds of phenomena: rule-based, interesting stuff, and everything else, the memorized exceptions. It’s an empirical question whether separate and distinct mechanisms are responsible for regular, rule-like behavior and apparent exceptions to the rules. The fact that speakers
can mimic certain foreign stress patterns should not be dismissed lightly, for if a single mechanism handles both rules and exceptions, our theory of that mechanism must ultimately account for the exceptions as well as the rules.

Even if we accept the proposal that deviant noun forms like those in (19a) are extragrammatical, memorized exceptions, we are faced with deviant verb forms like those in (19b). In Spanish nouns, prevocalic as well as postvocalic glides contribute to syllable weight (cf. Carreira, 1992; Harris, 1983, 1995a; Roca, 1991). Thus noun forms like *só.sie.go, with an unstressed penultimate diphthong, are systematically excluded from the language. Either the relationship between syllable structure and syllable weight is different for nouns and verbs in Spanish, or the words in (19b) exhibit unstressed heavy penults. Again, we’re faced with the existence of forms which are simply not compatible with a quantity-sensitive analysis. These forms, though, cannot be classified as memorized exceptions, because the suffixes which condition antepenultimate stress here are regular, productive verb inflections. Harris (1995a) suggests that although noun stress is quantity-sensitive, verb stress is not. Given the similarity between verbal and nominal stress patterns in every other respect, this supposed difference seems rather suspicious. The suspicion is heightened by the fact that the verb inflections cited by Harris in support of a quantity-insensitive analysis of verb stress involve only one or two inflectional affixes, and only certain dialects. In standard Spanish, antepenultimate verb stress occurs only with inflections which guarantee light penults. The standard forms corresponding to those of (19b) have penultimate stress (lim.pié.mos, en.vi.dié.mos, a.ca.ri.cié.mos), and therefore reveal nothing about the relationship between antepenultimate stress and syllable weight in Spanish.

In verbs, as in nouns, a few idiosyncratic morphemes (literally one or two verb inflection affixes in only some dialects) condition violations of the otherwise valid generalization that heavy penults are stressed. Stress placement in Spanish is SENSITIVE to syllable structure, but not a SLAVE to it. While penultimate stress is the canonical pattern, unstressed light penults also occur but are relatively marked, and unstressed heavy penults are even more highly marked. These stress patterns can be better understood in terms of numerical constraints on stress eligibility.

The canonical penultimate stress of Spanish can be modeled by the NMC constraints proposed in §3.1.1–3.1.4. These constraints represent syllable weight and the sensitivity of stress to the right edges of words as well as noun and verb stems. Except for words of the sort cited in (19), Spanish words with antepenultimate stress have light penultimate syllables. As suggested in §3.1.1 and §3.1.4, antepenultimate stress can be accounted for by associating [-UP] with certain vowels in the lexical entries of the relevant forms. Consider the task of a language learner, faced with forms like termodinámico, orgánico, telefónico, or any of the forms in (19) above. The learner is confronted in each of these forms with a penultimate vowel which surfaces with an unexpectedly low level of prominence. I suggested above that a language learner employs just enough [UP] to render the penults ineligible for stress in words like telefónico. The same strategy will work with the forms in (19), though they require stronger [UP] to overcome the weight of their heavy penults, as demonstrated in (20).
Since the edge biases for nouns and verbs are different (cf. §3.1.3), it will be convenient to analyze violations of quantity-sensitivity separately for nouns and verbs, though the analyses will be parallel. I will begin with the verbs, since the forms of (19b)

(A) Most inflections which produce antepenultimate stress need only a small [-UP] because they deal only with light penults, as in cocinábamos. (B) Some dialects also have inflections which produce antepenultimate stress in environments where heavy penults are possible, and these require a stronger [-UP] to produce antepenultimate stress in words like envíamos. (C) Strong [-UP] can also render heavy penults ineligible for stress in noun forms, producing antepenultimate stress in words like Wáshington. Wt=syllable weight, WE=word edge bias, NSE=stem edge bias, VSE=stem edge bias, [UP]=underlying prominence.

Since the edge biases for nouns and verbs are different (cf. §3.1.3), it will be convenient to analyze violations of quantity-sensitivity separately for nouns and verbs, though the analyses will be parallel. I will begin with the verbs, since the forms of (19b)

are unquestionably productive, and cannot plausibly be classified as extragrammatical. In §3.1.4, I discussed verb inflections with unstressed light penults, and showed that those forms required [-UP] of about –0.26. Since this amount of underlying prominence is just barely enough to render a light penult ineligible for stress, it would not be sufficient to render a heavy penult ineligible for stress. However, the task faced by the learner is essentially the same. When faced with a form like acariciemos, the learner is confronted with a word which unexpectedly has an unstressed penult. The weakest [-UP] which will render an unstressed heavy penult ineligible for stress is –1.26. The learner can simply create an appropriate lexical entry with this amount of underlying prominence on the relevant vowel. On this account, the process for learning is the same regardless of the weight of the penultimate syllable, but the amount of [-UP] required depends on the syllable weight. Moreover, since most lexical entries that have the weaker amount of [-UP], the few that require the stronger [-UP] will stick out like sore thumbs.

The deviant noun forms of (19a) are accounted for in a parallel fashion. As shown in §3.1.1, a [-UP] of –0.36 is just enough to render a light penult in a noun form ineligible for stress. In contrast, the weakest [-UP] which will render the heavy penult of Frómista or Wáshington ineligible for stress is –1.36. Again, the learner should have no trouble figuring out how to represent the deviant forms in the lexicon, but those lexical entries will be phonologically unusual compared to the rest of the lexicon.

This account does not claim that Spanish words which violate quantity-sensitivity are just as “normal” as other words with unstressed penults. It does give a PHONOLOGICAL account of the difference between these forms. The surface stress pattern of Frómista or acariciemos is similar to that observed in other words with antepenultimate stress, like termodinámico, but the corresponding lexical entries have different amounts of information about stress. The relative markedness of these forms
with respect to stress is accounted for by a specific difference in their lexical entries, namely the strength of the [UP] present in the lexicon.

If the regular stress process employed by Spanish speakers can accommodate words with heavy unstressed penults, like *Frömista*, why are similar nonce forms like those given in (18b) rejected as deviant? This seems paradoxical, but only if one assumes that grammaticality judgments of nonce forms literally and accurately reflect the bounds of grammaticality, i.e. what actual words could or could not be accommodated by the grammar of a language. In contrast, if “grammaticality judgments” actually reflect something like perceived typicality of nonce forms relative to the actual vocabulary of a language, there is no paradox. Rejected nonce forms like *túnanbo* or *écánsta* are similar in relevant respects to words in the *Frömista* class, but this class consists mostly of nonnative vocabulary AND it involves highly unusual underlying representations. Speakers reject these nonce forms because they involve phonological representations which deviate in a particular quantitative way from the vast majority of native Spanish words.

3.1.6. Summary and Conclusion

The NMC framework suggests a new way of looking at stress phenomena in terms of constraints on the eligibility of each syllable to bear stress. If we translated the proposed account of Spanish into the language of phonological features, we might say that while stress is underspecified in most forms, unstressed light penults involve an underlying feature like [−1 STRESS], and unstressed heavy penults involve [−2 STRESS]. This sounds pretty ugly in a system based on symbol manipulation, but it’s perfectly natural in a model based on quantitative constraint interactions. In any event, the proposed account requires richer underlying representations than those allowed either by a privative metrical grid, or a binary feature system. These representations are motivated by the principles of simplicity of underlying representations and recoverability of surface forms from those underlying representations. With these richer underlying forms, the relative markedness of various stress patterns is directly reflected in phonological representations. A single quantity-sensitive process, combined with metrical biases in the lexicon, can account for Spanish stress in both nouns and verbs, and for apparent counterexamples to quantity-sensitivity.

The idea that lexical representations can specify negative as well as positive [UP] for particular vowels allows the NMC model to account for the behavior of vowels which idiosyncratically repel stress. Negative [UP] was crucial in accounting for lexical stress in Spanish without resorting to arbitrary diacritics, and [-UP] will likewise play a central role below in accounting for lexical stress in Polish.
3.2. Polish

The NMC theory of primary stress maintains that the location of primary stress can be established directly, without first establishing a rhythmic pattern of secondary prominence. The theory also maintains that lexical stress involves underlying prominence, which can serve as a constraint either for or against stress on particular vowels. The stress patterns of Polish provide further confirmation that the first claim is correct, and also illustrate the need for underlying prominence or a similar theoretical device for enhancing or depressing the eligibility of a vowel to bear stress.

Metrical analyses of Polish stress can be found in Franks (1991), Halle & Vergnaud (1987b:57), Hammond (1989), Iosardi (1992:14), and Rubach & Booij (1985). As in Spanish, the location of primary stress in Polish is autonomous with respect to secondary stress. This is demonstrated by the fact that rhythmic secondary stress is established from left to right, while primary stress is located relative to the end of a word. Primary stress in Polish falls on the penultimate syllable of a word, and secondary stress falls on odd-numbered syllables counting from the beginning of the word (but not on a syllable adjacent to primary stress). This can be seen clearly in forms like rewolucjonista ‘revolutionary’ (nominative) and rewolucjonistami (instrumentative plural) (Rubach & Booij, p. 296):

(21) 

```
rebojlonista rewolucjonisti
```

The penultimate primary stress of rewolucjonistami makes it clear that primary stress in Polish is not derived by first establishing the rhythmic pattern of alternating secondary stress, and then designating one of the stressed syllables the primary stress.

Rather, primary stress is established independently of secondary stress. Secondary stress depends on primary stress to the extent that secondary stress is excluded from the syllable preceding primary stress. Rubach & Booij also present evidence that secondary stress applies to phrases while primary stress applies to individual words. With the autonomy of primary stress in Polish established, I will focus on the details of primary stress assignment and will have nothing further to say about the rhythmic, metrical secondary stresses.

In the default case, primary stress in Polish falls on the penultimate syllable, and penultimate stress is maintained under suffixation, as illustrated in (22a–a’). Deviations from penultimate stress occur in three classes of nouns. In the P/A class, illustrated in (2b–b”), stress surfaces on the penultimate syllable of the bare stem, but on the antepenultimate syllable when the stem is followed by a one-syllable suffix; stress is penultimate when the stem is followed by a two-syllable suffix. The A/P class of nouns, illustrated in (2c–c”), also exhibits antepenultimate stress, but only on the bare stem; penultimate stress is observed when the stem is followed by either a one- or two-syllable suffix. Finally, the F/P class of nouns, illustrated in (2d–d”), exhibits final stress in bare stem forms, and penultimate stress in suffixed forms.12

12Rubach & Booij ([1985 #148:287]) note that stems which exhibit deviations from penultimate stress lose their special stress properties under derivational suffixation, much as Spanish verb stems lose special stress properties observed in related nouns (see §3.1.3). I make no attempt here to account for these facts of Polish, though they appear to be open to analysis in terms of additional edge biases as an incremental refinement of the analysis I propose in the text.
(22) Polish Stress Patterns

<table>
<thead>
<tr>
<th>Noun Class</th>
<th>No Suffix</th>
<th>1-Syl Suffix</th>
<th>2-Syl Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>a. hipopotam</td>
<td>a'. hipopotam-a</td>
<td>a''. hipopotam-ami</td>
</tr>
<tr>
<td>P/A</td>
<td>b. gramatyk</td>
<td>b'. gramatyk-a</td>
<td>b''. gramatyk-ami</td>
</tr>
<tr>
<td>A/P</td>
<td>c. uniwersytet</td>
<td>c'. uniwersytet-u</td>
<td>c''. uniwersytet-ami</td>
</tr>
<tr>
<td>F/P</td>
<td>d. rež im</td>
<td>d'. rež im-u</td>
<td>d''. rež im-ami</td>
</tr>
</tbody>
</table>

Polish nouns exhibit default penultimate stress, (a–a’). Marked stems exhibit penultimate stress except for the boxed forms. P/A stems have antepenultimate stress when followed by a 1-syllable suffix, (b’). A/P stems have antepenultimate stress if not followed by a suffix, (c). F/P stems have final stress when not followed by a suffix, (d). Glosses: (a) ‘hipopotamus’, (b) ‘grammar’, (c) ‘university’, (d) ‘regime’.

The lexical stresses of Polish are readily analyzed in terms of underlying prominence features much like those proposed in the analysis of Spanish presented earlier in this chapter. Before presenting the NMC analysis of Polish, I will review metrical accounts proposed by Halle & Vergnaud (1987a) Franks (Franks, 1991), and by Idsardi (1992).

Halle & Vergnaud Account of Polish

The rules of Polish stress assignment proposed by Halle & Vergnaud (HV) are summarized in (23). Most of the work is done by (23c), which employs binary feet to place stress on even-numbered syllables counting from the end of the word, and then designates the rightmost stressed syllable the primary stress. Since this rule establishes the wrong pattern of secondary stress, HV invoke a rule of Tier Conflation to delete the second-highest row of marks on the metrical grid. The effect of Tier Conflation is to eliminate the extraneous stresses while preserving the primary stress, as described in (23d). The actual secondary stresses must be assigned by a later rule, which I will ignore. The resulting metrical structure for default noun forms is illustrated in (24a–a’).

(23) Halle & Vergnaud, 1987a:57

a. The syllable after specially-marked stems (P/A Class) is extrametrical
b. Certain noun stems (A/P Class) are represented in the lexicon with a final extrametrical syllable
c. Build left-headed binary feet from right to left, and assign stress to the head of the rightmost foot
d. Delete all stresses except the primary stress

For P/A stems, which exhibit antepenultimate stress when followed by a one-syllable suffix, HV propose a rule assigning extrametricality to the syllable following specially-marked stems. In other words, P/A stems carry a diacritic which invokes rule (23a). The effect of HV’s stress rules for P/A stems is illustrated in (24b–b’). In bare P/A stems, the structural description of the extrametricality rule (23a) is not met. There is no syllable following the stem, so there is no extrametricality. In contrast, when P/A stems are followed by a one-syllable suffix, the suffix is made extrametrical by (23a), so the head of the rightmost foot is the antepenultimate syllable. When followed by a two-syllable suffix, rule (23a) would assign extrametricality to the first syllable of the suffix. However, the universal Peripherality Condition limits extrametricality to a single constituent at the edge of the stress domain (Harris, 1983; Hayes, 1982). Since the first syllable of a two-syllable suffix is not word-final, it cannot be extrametrical, and normal penultimate stress is assigned to P/A stems when followed by a two-syllable suffix.
To account for the A/P stems, HV mark the final syllable of these stems extrametrical in the lexicon. The effect of lexical extrametricality is demonstrated in (24c–c'). When the stem occurs alone, extrametricality combines with left-headed binary feet to produce antepenultimate stress. When followed by a suffix, whether one or two syllables, the final syllable of the stem is not final within the stress domain, so its extrametricality is revoked by the Peripherality Condition, and normal penultimate stress is observed.

HV do not specifically address the F/P stems of Polish, but these stems could readily be described as cases of accent marked in the lexicon—this is the mechanism HV use for idiosyncratically stressed syllables in Akan, for example (HV, p. 20).

The HV analysis of lexical stress in Polish is open to criticism on several grounds. Binary feet are used to determine the location of primary stress, though no independent evidence is provided that the stressed syllable and the one following it behave as a constituent. HV not only employ binary feet, but parse the entire word into binary feet with their associated stresses, and then delete all but the primary stress. The intermediate representation, before Tier Conflation, has abstract stresses with no empirical consequences. This abstractness is a result of locating primary stress on top of a secondary stress rather than establishing primary stress independently.

Perhaps worst of all, the HV analysis of lexical stress involves a different theoretical device for each different pattern of lexical stress. The P/A stems involve rule-invoking diacritics, the A/P stems involve lexical extrametricality, and if the analysis is extended in the obvious way to F/P stems, these would involve lexical accent marks. The need for different theoretical machinery for every different pattern of lexical stress suggests that the general theory is not well-equipped to deal with lexically-governed deviations from default stress patterns.

Finally, as I noted in the discussion of lexical stress in Spanish, rule-invoking diacritics are arbitrary and unconstrained, and it would be preferable to account for phonological generalizations in terms of phonological representations rather than rearranging the grammar for particular lexical entries (cf. Harris, 1985; Inkelas, 1994a; McCarthy, 1988).

**Franks Account of Polish**

A clever alternative to the HV account is proposed by Franks (1991). Franks analyzes both P/A stems and A/P stems in terms of lexically-marked extrametrical vowels, thereby reducing the number of different mechanisms required for Polish marked stress patterns to two—lexical extrametricality for P/A and A/P stems, and lexical accent for F/P stems. This reduction in theoretical machinery comes at the price of abstractness, however: P/A and A/P stems are represented in the lexicon with an empty vowel slot, e.g. $\text{CVCCV}<\text{V}>$ for P/A stems, and $\text{CVCCV}<\text{V}>\text{CV}$ for A/P stems. These
abstract vowel slots link to the first vowel of a suffix, if present; if there is no suffix they delete before the stress rules apply. Like the HV account, Franks employs binary feet to assign primary stress, and parses the entire word into feet which must evidently be subsequently deleted by Tier Conflation.

Idsardi Account of Polish

Idsardi (1992:14) gives an account of lexical stress in Polish which avoids special rules invoked by diacritics, and employs a common mechanism for all three lexical stress patterns. The theory of stress proposed by Idsardi emphasizes the role of edges marking the boundaries between metrical constituents, so that the left and right edges of metrical feet can be manipulated independently of each other. In other words, a phonological representation can include explicit left or right constituent boundaries, with or without matching right or left boundaries, respectively. The rules essential to Idsardi’s analysis of Polish are summarized in (25).

(25) Idsardi (1992:15)
   a. P/A stems have a lexical right edge after their final vowel: \( \ldots \sigma \)\( \sigma \)
   b. A/P stems have a lexical right edge after their penultimate vowel: \( \ldots \sigma \)\( \sigma \)
   c. F/P stems have a lexical left edge before their final vowel: \( \sigma \)\( \sigma \)
   d. Build left-headed binary feet from right to left, and assign stress to the head of the rightmost foot
   e. (Delete all stresses except the primary stress)

For Idsardi, as for HV, default penultimate stress is assigned by left-headed binary feet, established by (25d), and extraneous stresses are eliminated by (25e).\(^{13}\) Idsardi’s analysis diverges from HV’s in attributing lexical stress to underlying metrical structure rather than diacritics and lexical extrametricality. The underlying representations and resulting metrical structures proposed by Idsardi are illustrated in (26).

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>P/A</th>
<th>A/P</th>
<th>F/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>( \ldots \sigma )</td>
<td>( \ldots \sigma )</td>
<td>( \ldots \sigma )</td>
<td>( \ldots \sigma )</td>
</tr>
<tr>
<td>b.</td>
<td>( \ldots \sigma )( \sigma )</td>
<td>( \ldots \sigma )( \sigma )</td>
<td>( \ldots \sigma )( \sigma )</td>
<td>( \ldots \sigma )( \sigma )</td>
</tr>
<tr>
<td>c.</td>
<td>( \sigma )( \sigma )</td>
<td>( \sigma )( \sigma )</td>
<td>( \sigma )( \sigma )</td>
<td>( \sigma )( \sigma )</td>
</tr>
</tbody>
</table>
| d.    | Build left-headed binary feet from right to left, and assign stress to the head of the rightmost foot
| e.    | (Delete all stresses except the primary stress)

\(^{13}\)The deletion rule (25e) is inferred based on the secondary stress facts of Polish. Idsardi doesn’t specifically mention the deletion of extraneous stresses for Polish, but some such move is evidently required. Idsardi’s account of Macedonian is more explicit in this regard, and does invoke an operation of metrical conflation similar to (25e), eliminating all metrical structure except the stressed foot ([Idsardi, 1992 #46:9]).
of a foot, and this overrides the general restriction against one-syllable feet, producing final stress in bare stems as shown in (26d).

The Idsardi analysis succeeds in assigning default and lexical stress patterns of Polish with a single set of stress rules, combined with lexical representations marking critical metrical boundaries. This analysis relies on the observation that certain vowels in P/A and A/P stems are lexically stressless, and the final vowel in F/P stems is lexically stressed unless it is too far from the end of the word. Still, like the HV and Franks analyses, Idsardi’s account of primary stress in Polish relies on binary feet to establish the location of primary stress, with no independent evidence that the stressed syllable and the syllable following it actually behave as a constituent. All three analyses also involve an intermediate derivational representation with alternating stresses which must be deleted.

**NMC Account of Polish Stress**

An insight shared by the analyses of lexical stress in Polish reviewed above is that the stress pattern induced by marked stems depends on the location of the stem relative to the end of the word. The effect of marked stems is **LOCALIZED**—when a marked stem is relatively distant from the end of the word (e.g. when followed by a two-syllable suffix), it has no effect on stress placement and default penultimate stress is assigned. For HV and for Franks, this localization is a result of the Peripherality Condition on extrametricality. For Idsardi, localization results from a language-particular ban on single-syllable feet. In the NMC framework, localization results from interactions between underlying prominence and gradient edge biases.

The canonical penultimate stress of Polish requires a negative edge bias at the end of the word, strong enough to overcome the weight of the final syllable. In this respect Polish is similar to Spanish. If **H** designates the weight of the heaviest final syllable in Polish, then the weakest word edge bias sufficient to consistently render the final syllable ineligible for stress is −**H**. As demonstrated in (27), such an edge bias will guarantee that the final syllable will be ineligible for stress, while leaving the penult eligible, regardless of the actual weight of these syllables in particular words. Combined with the End Rule, this edge bias will produce uniform penultimate stress.14

(27) Stress Eligibility in Polish

<table>
<thead>
<tr>
<th>A</th>
<th>Wt + WE = Wt+WE</th>
</tr>
</thead>
<tbody>
<tr>
<td>H ... H H</td>
<td>[X ... X X]</td>
</tr>
</tbody>
</table>

(A) A negative edge bias at the end of a word offsets the weight of a final heavy syllable. (B) The word edge bias reduces the eligibility of the penult, but a light penult is still eligible to bear stress. **Wt**=syllable weight, **WE**=word edge bias, **H**=heavy syllable, **L**=light syllable.

---

14Polish stress assignment places default stress on the penultimate syllable regardless of syllable structure. In the analysis of Polish I assume that differences in syllable weight are inherent in different syllable structures, whether or not a stress system makes use of the distinction between light and heavy syllables. The analysis of Polish could be slightly simpler if all syllables were assumed to have the same weight.
The lexical stress patterns of Polish can be analyzed in terms of individual vowels with [UP]. Equations deriving the specific amount of [UP] required are given in Appendix B.2. In P/A stems, the last vowel of the stem never bears stress, even when it’s the penultimate vowel of the word. The simplest analysis of these stems is to assign the last vowel of the stem [-UP] in the underlying representation. To prevent this vowel from being eligible for stress in penultimate position, the [-UP] must cancel the combined effect of the syllable weight and the edge bias on the penultimate syllable. As demonstrated in (28), this [-UP] will produce antepenultimate stress when the stem is followed by a one-syllable suffix, and penultimate stress otherwise. This analysis assumes that the language learner employs just enough underlying prominence to render a vowel ineligible for stress in those environments where the vowel idiosyncratically surfaces without stress. If the penultimate syllable is light, a weaker [-UP] would suffice, but the analysis would otherwise be identical.

In a similar way, the second-to-last vowel of A/P stems (counting from the end of the stem, not the end of the word) is idiosyncratically unstressed. A/P stems require exactly the same [-UP] as P/A stems, but for A/P stems it’s the second-to-last stem vowel which bears [-UP] rather than the last stem vowel, as shown in (29).

Whereas the P/A and A/P stress patterns involve vowels which are idiosyncratically unstressed in penultimate position, the F/P stems have a vowel which is idiosyncratically stressed when in final position. These vowels have a [+UP] feature, which increases their eligibility to bear stress. Here, the language learner employs just

---

15This aspect of the analysis resembles the plus or minus [stressable] feature employed by Comrie ([, 1976 #147], cited by Franks [, 1991 #146]). However, in the NMC framework [UP] functions as a numerical constraint on stress eligibility, and [UP] is not restricted to a binary plus-or-minus distinction.

----

(28) Stress Eligibility in P/A Nouns

A

\[ \text{Wt+WE} \]

\[ [H \ H \ H] \]

\[ [X \ X \ X]\]

\[ [[H \ H \ H]] \]

B

\[ \text{Wt+WE} \]

\[ [H \ H \ H \ H] \]

\[ [X \ X \ X \ ]\]

\[ [[H \ H \ H \ H]] \]

C

\[ \text{Wt+WE} \]

\[ [H \ H \ H \ H \ H] \]

\[ [X \ X \ X \ X \ ]\]

\[ [[H \ H \ H \ H \ H]] \]

In P/A stems, like gramatyk, gramatyk-a, gramatyk-dni, [-UP] on the last vowel of the stem produces antepenultimate stress when the stem is followed by a 1-syllable suffix. (A, B and C) correspond to words with a bare stem, a 1-syllable suffix, and a 2-syllable suffix, respectively.

Schematic underlying representations for the four types of Polish nouns are shown in (30). The three observed patterns of lexical stress exhaust the possibilities of stress patterns which can be produced by associating positive or negative [UP] with a single stem vowel. Placing [-UP] on a vowel more than two syllables from the end of the stem would have no effect on the placement of primary stress, since there would always
(29) Stress Eligibility in A/P Nouns

A

\[ Wt+WE \quad \text{[UP]} \quad \text{Eligibility} \]

\[ [H \ H \ H] \quad [X \ X \ X] \quad [H \ H \ H] \]

B

\[ Wt+WE \quad \text{[UP]} \quad \text{Eligibility} \]

\[ [H \ H \ H] \quad [X \ X \ X] \quad [H \ H \ H] \]

C

\[ Wt+WE \quad \text{[UP]} \quad \text{Eligibility} \]

\[ [H \ H \ H \ H] \quad [X \ X \ X \ X] \quad [H \ H \ H \ H] \]

In A/P stems, like *uniwersytet*, *uniwersitět-u*, *uniwersitet-dni*, [-UP] on the penultimate vowel of the stem produces antepenultimate stress when the stem is not followed by a suffix. (A, B and C) correspond to words with a bare stem, a 1-syllable suffix, and a 2-syllable suffix, respectively.

be at least one vowel farther to the right eligible for stress. Similarly, placing [+UP] more than one syllable from the end of the stem would have no effect on the placement of stress since the word edge bias would render the final syllable ineligible for stress and stress would simply fall on the penultimate syllable.

The final patterns of stress eligibility for the four types of stem are laid out in (31). In each case, the rightmost vowel with stress eligibility greater than zero corresponds to the observed location of stress.

(30)

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>P/A</th>
<th>A/P</th>
<th>F/P</th>
</tr>
</thead>
<tbody>
<tr>
<td>[-UP]</td>
<td>[-UP]</td>
<td>[+UP]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| hipopotam gramatyk uniwersytet rež im |

Discussion

In some respects the NMC analysis is similar to the edge-marking analysis proposed by Idsardi. Idsardi’s analysis accounts for the three patterns of lexical stress in Polish with a single theoretical device: individual foot boundaries in the lexicon specify that certain vowels should or should not be placed in head position of metrical feet, rendering them inherently stressed or stressless in appropriate environments. This analysis is an improvement over the HV analysis which required special rules invoked by diacritics, and different theoretical machinery for each different pattern of lexical stress. The NMC analysis also accounts for the three patterns of lexical stress in Polish with a single mechanism, [UP] associated with individual vowels in the lexicon. The differences between the three patterns of lexical stress are a function of which vowel the [UP] feature is associated with and whether the [UP] is positive or negative. Like a [astress] feature, [UP] is a reflection of otherwise unpredictable surface prominence. However, unlike a [astress] feature, [UP] is a numerical constraint on stress eligibility, and not an all-or-nothing declaration about the actual prominence of a particular vowel.

Like HV and many others, Idsardi assumes that primary stress assignment is a reflection of metrical constituent structure. The NMC account questions this assumption, and models the same stress patterns without relying on constituent structures and all the theoretical machinery associated with them.
(31) Stress Eligibility for Polish Noun Stems

<table>
<thead>
<tr>
<th></th>
<th>No suffix</th>
<th>1-Syl suffix</th>
<th>2-Syl suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Eligibility</td>
<td>Eligibility</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[H H H]</td>
<td>[H H H]</td>
<td>[H H H]</td>
</tr>
<tr>
<td>B</td>
<td>Eligibility</td>
<td>Eligibility</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[H H H]</td>
<td>[H H H]</td>
<td>[H H H]</td>
</tr>
<tr>
<td>C</td>
<td>Eligibility</td>
<td>Eligibility</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[H H H]</td>
<td>[H H H]</td>
<td>[H H H]</td>
</tr>
<tr>
<td>D</td>
<td>Eligibility</td>
<td>Eligibility</td>
<td>Eligibility</td>
</tr>
<tr>
<td></td>
<td>[H H H]</td>
<td>[H H H]</td>
<td>[H H H]</td>
</tr>
</tbody>
</table>

(A) Unmarked stems receive penultimate stress, e.g. hipopotam, hipopotám-a, hipopotám-ámi. (B) In P/A stems, [-UP] lowers the eligibility of the last vowel of the stem, producing antepenultimate stress when followed by a 1-syllable suffix, e.g. gramátyk, gramátyk-a, gramátyk-ámi. (C) In A/P stems, [-UP] lowers the eligibility of the second-to-last vowel of the stem, producing antepenultimate stress in bare stems, e.g. uniwersytet, uniwersytét-a, uniwersytét-ámi. (D) In F/P stems, [+UP] raises the eligibility of the last vowel of the stem, producing final stress in bare stems, e.g. reż ím, reż ím-u, reż ím-ámi.

3.3. Latin Enclitic Stress

One of the goals of this work is to show that many stress patterns which have been analyzed in terms of foot construction followed by primary stress assignment are better described in terms of autonomous constraints on primary stress. The primary stress pattern of Latin is one of those which has been analyzed in terms of foot construction, and interactions between stress and clitics in Latin have been used to argue not only that primary stress assignment depends on metrical feet, but that the existence of these feet is confirmed by their influence on subsequent stress rules (Halle & Kenstowicz, 1991; Kenstowicz, 1993; Steriade, 1988). Although enclitic stress in Latin clearly demonstrates that stress assignment is sensitive to morphological structure, those stress patterns are readily described in terms of nonmetrical constraints on stress, and metrical constituents are not in fact needed to account for the location of primary stress in Latin.

In Classical Latin, stress in non-cliticized words falls on the penultimate syllable if it is heavy (closed syllables and syllables with long vowels are heavy in Latin). If the penult is light, stress falls on the antepenultimate syllable. Enclitics like -que, -propter, and -ināe attract stress onto the immediately preceding syllable, i.e. the last syllable of the host word, regardless of syllable structure in either the clitic or the host (my description of these data relies primarily on Halle & Kenstowicz, 1991; Mester, 1994; and Steriade, 1988). These stress patterns are illustrated in (32).\(^{16}\)

\(^{16}\)Mester (p. 48) cautions that this description of enclitic stress in Latin is controversial, and may reflect imitation of Greek grammars rather than actual Latin pronunciations. I assume here the accuracy of this description in order to demonstrate how such a stress pattern would be modeled in terms of constraints on stress eligibility—a description of just the non-controversial non-enclitic stress pattern would be somewhat
(32) **Latin Stress**

<table>
<thead>
<tr>
<th>Weight of penult</th>
<th>No clitic</th>
<th>1-Syl clitic</th>
<th>2-Syl clitic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>a. lli.mi.na</td>
<td>a'. lli.mi.ní-que</td>
<td>a&quot;. u.bí-libet</td>
</tr>
<tr>
<td></td>
<td>scéle.ra</td>
<td>sce.le.rí-que</td>
<td>al.té.r-in.ter</td>
</tr>
<tr>
<td></td>
<td>ho.mi.ní.bus</td>
<td>muu.sá-pe</td>
<td>pro.pé-di.em</td>
</tr>
<tr>
<td>Heavy</td>
<td>b. a.mí.ca</td>
<td>b'. ho.mi.néex-que</td>
<td>b&quot;. e.áa-prop.ter</td>
</tr>
<tr>
<td></td>
<td>po.tés.taas</td>
<td>ho.mi.ní.bús-que</td>
<td>id-sír.co</td>
</tr>
<tr>
<td></td>
<td>Roo.mía.nii</td>
<td></td>
<td>súb-in.de</td>
</tr>
</tbody>
</table>

When no clitic is present, stress is (a) antepenultimate if the penultimate syllable is light, or (b) penultimate if the penultimate syllable is heavy. When a clitic is present, stress falls on the last syllable of the stem regardless of syllable weight, as shown in (a', a"', b', b''). Clitics are underlined, long vowels are represented as double vowels, and periods mark syllable divisions. Glosses: (a) ‘thresholds’, ‘crimes’, ‘to the men’; (a') ‘and the thresholds’, ‘and the crimes’, ‘whether the Muse’; (a'') ‘wherever’, ‘one of two’, ‘any day now’; (b) ‘friend-feminine’, ‘power’, ‘Romans’; (b') ‘and men’; (b'') ‘therefore’, ‘for this reason’, ‘immediately thereafter’

**Metrical Analyses of Latin Stress**

Steriade (1988) suggested that the proper treatment of stress in Latin requires a distinction between two levels of morphosyntactic constituent structure. **W-words** correspond to single words to which a clitic may or may not be attached, and **E-words** correspond to the larger domain encompassing a W-word optionally followed by an enclitic suffix. The structures \([{\text{scélera}}]_w\), \([{\text{scélera}}]_n\), \([\text{que}]_e\), and \([{\text{ubi}]_n\ libet}]_e\), for example, are attributed to the words *scélera, scelerá-que, and ubi-libet*, respectively.

Steriade then proposed that stress in Latin host+clitic forms could be described by assigning metrical structure twice—first to the W-word host alone, then to the whole host+clitic E-word. Halle & Kenstowicz (1991, henceforth HK) adopt this suggestion and integrate it into the framework of Lexical Phonology (Halle & Vergnaud, 1987a; Kiparsky, 1982) by assigning W-words to the ‘cyclic’ stratum of rules and clitics to the subsequent ‘noncyclic’ stratum.\(^\text{13}\) The essence of the Steriade/HK analysis is captured by the rules in (33).
Latin Stress Rules

First Round—W-word
a. Final syllable is extrametrical
b. Build quantity-sensitive left-headed binary feet from right to left

Second Round—E-word
c. Final syllable is extrametrical
d. Build quantity-insensitive left-headed binary feet from right to left (respecting existing feet)
e. Assign primary stress to the rightmost stressed syllable (foot head)

What makes this analysis work is the assumption that constituents built by earlier rules constrain the action of subsequent rules. The first round of stress assignment places stress on the penultimate or antepenultimate syllable of the W-word by building metrical structures like those shown in (34A). Since the final syllable of the W-word is extrametrical during the first round of stress assignment, it is not placed in a foot during that round and is therefore available for stressing in the second round, as illustrated in (34B). The second round of stress assignment attempts to organize the antepenultimate and penultimate syllables of an E-word form into a binary constituent. However, because foot construction is assumed to be structure-preserving, any syllable which was already incorporated into a foot during the first round of stress assignment will not be available to the second round of stress assignment. Antepenultimate stress is precluded in words with one-syllable clitics, like liiminá-que, because when the second round of stress assignment occurs the antepenultimate syllable is already part of a foot. The net result is that stress in host+clitic forms lands on the final syllable of the W-word, as illustrated in (34C).

There’s an empirical problem with the Steriade/HK analysis, as noted by Idsardi (1993:24), and also by Mester (1994:50). When a two-syllable clitic is attached to a monosyllabic W-word, as in quaa-propéter, the Steriade/HK stress rules incorrectly predict that stress will fall on the first syllable of the clitic, yielding *quaar-propéter, with the metrical structure of (34D). Incorrect assignment of stress to forms of this shape is a side-effect of the very constituent structure crucial to the analysis of words with one-syllable clitics, like liiminá-que.

Idsardi (1993) proposes a variation of the Steriade/HK analysis which solves the problem posed by forms like quaa-propéter. The stress rules proposed by Idsardi assign an open-ended foot to one-syllable W-words, resulting in partial metrical structures like quaa after the first round of stress assignment, where the lone left bracket represents the left edge of an open-ended foot. Leaving this foot open-ended allows the second round rules to integrate the W-word syllable into a full binary foot if the W-word is followed by a two-syllable clitic, producing metrical structures like (quaa-propéter). Idsardi leaves the Steriade/HK analysis of words with longer W-words essentially intact, so that the integrity of constituents built by the first round rules continues to be crucial in Idsardi’s analysis.
(34) Metrical Analysis Of Latin Enclitic Stress (Halle & Kenstowicz, 1991)

A (* .) ( . ) ( . ) < > stress
lii.m.i.na u.bi e aa syllables

B (* .) : ( * . ) : ( * . ) : stress
lii.m.i.na que u.bi.li.bet e aa.prop.ter syllables

C ( . . *) ( . *) . ( . *) . ( . *) . Iry stress
(* *) (*) ( *) . ( *) . ( * *) . stress
lii.m.i.na que u.bi.li.bet e aa.prop.ter syllables

D ( . *) Iry stress
(* *) < > stress
lii.m.i.na que u.bi.li.bet e aa.prop.ter syllables

*quaa.prop.ter

Stress is assigned in two passes. (A) The first pass applies to W-words, ignoring clitics, with final-syllable extrametricality and left-headed binary feet. (B) The second pass includes clitics—the last syllable of the W-word is not final and so is no longer extrametrical. (C) A second round of foot construction applies, and primary stress is assigned to the rightmost stressed syllable. (D) Stress is incorrectly assigned when a two-syllable clitic attaches to a monosyllabic W-word.

Although Idsardi’s analysis solves the quáa-propter problem, there are additional problems with the Steriade/HK analysis which transfer to the Idsardi edge-marking variation, as well. For all these analyses, it’s crucial that the stress rules leave the final syllable of a W-word unmetrified (extrametrical) so it will be available to subsequent rules. However, evidence from Iambic Shortening (Brevis Brevians) and Cretic Shortening suggests that the final syllable of Latin words is actually placed in a foot and is not, in fact, left unmetrified (Mester, 1994). These shortening processes will be discussed briefly below. The Steriade/HK/Idsardi analysis also places the primary stress on the rightmost stressed syllable, i.e. the head of the rightmost foot. However, if the final syllable is not extrametrical but is placed in a foot in order to account for Iambic and Cretic Shortening processes, then the primary stress will often surface on the head of the second-to-last foot and will not consistently be placed on the head of the rightmost foot as required by the Steriade/HK/Idsardi analysis.

In Early Latin, an optional process (Iambic Shortening) shortened the final syllable of two-syllable words consisting of a short-long sequence, e.g. pāqua → pāqa. As Mester notes, Iambic Shortening applies to a form which cannot be parsed into bimoraic feet, and renders a form which is parsable as a single bimoraic foot. If proper footing provides the motivation for Iambic Shortening, as Mester argues, then the final syllable cannot simply be extrametrical as assumed by the stress rules proposed by Steriade/HK/Idsardi.

A process known as Cretic Shortening also provides evidence against final-syllable extrametricality in Latin. Cretic Shortening applies to the final syllable of words ending in a long-short-long sequence, allowing them to be scanned in verse as short syllables: dīcitō → dīcito ‘say’, dēēsino → dēēsino ‘cease’, etc. Again, Mester argues that this process can best be understood in terms of optimal foot parsing. There’s simply no way to place all the syllables of a word of the form [ō ō ː] into bimoraic feet. As with Iambic Shortening, the result of Cretic Shortening is a fully parsable form, [(ō) (ō ː)]. Both processes make sense only if the final syllable is metrified.

If the final syllable must be included in metrification, as Iambic Shortening and Cretic Shortening suggest, then we must abandon the notion that primary stress in Latin

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18 The Optimality Theory analysis of Latin stress proposed by Hung ([, 1994

#124:190]) also runs afoul of evidence that the final syllable of Latin words is placed in a foot.
picks out the head of the rightmost foot. Indeed, we must conclude with Mester that
metrification takes place after primary stress assignment rather than vice versa. It won’t
do to simply parse a word into bimoraic feet and then assign primary stress to the head of
the penultimate foot. This would incorrectly predict stress four syllables from the end in
words ending in four light syllables, e.g. *(répriðmēre) ‘to repress’ (with parentheses
showing foot structure). Such words in fact exhibit stress three syllables from the end,
reprimere. Even if the feet could somehow be manipulated so that primary stress always
fell on the head of the penultimate foot, such a scheme would be incompatible with the
Steriade/HK/Idsardi analysis of enclitic stress, which relies on the final syllable of a host
word being unmetrified so that it’s still available during the second round of stress
assignment.

Recognizing the incompatibility of independently motivated foot structure with
the needs of primary stress assignment, Mester suggests that primary stress in non-clitic
forms involves construction of a single foot, with the rest of the word being parsed into
feet after primary stress assignment. Noting that stress never lands on a clitic, Mester
suggests that the entire clitic is simply extrametrical, and that stress is assigned to the
final syllable of the host in host+clitic forms, by application of the End Rule. Mester’s
use of the End Rule rather than binary feet to place stress on the final syllable of a host
word sidesteps the issue of whether or not rules of foot construction must respect
previous foot structure. Since Mester’s analysis of enclitic stress in Latin does not rely
on the metrical structure of earlier rules constraining the action of later rules, it
undermines the argument first made by Steriade that Latin enclitic stress confirms the
existence of earlier constituent structures.

Although Mester employs a binary foot to assign primary stress in non-clitic
forms, he offers no independent evidence that primary stress actually depends on foot
construction at all. An equally tenable claim is that primary stress and foot construction
are distinct and largely autonomous processes.19 The question then is how to restrict
stress to the penultimate or antepenultimate syllable without using binary feet, and the
answer is to be found in nonmetrical constraints on the eligibility of vowels to bear stress.

Constraints on Stress Eligibility in Latin

There is a key insight at the heart of Steriade’s analysis of Latin enclitic stress.
Two morphological domains are relevant for stress assignment: the W-word and the
E-word. In the absence of a clitic, these two domains are coextensive. When a clitic is
present, the W-word is smaller than the E-word and the syllables of the clitic lie outside
the domain of the W-word. Stress in Latin is simultaneously retracted away from the end
of E-words and attracted toward the end of W-words, and we can describe these effects in
terms of edge biases.

Consider first the behavior of stress relative to two-syllable clitics, in words like
eāa-propter. The absence of stress within the clitic suggests a negative bias at the end of
the E-word, strong enough to render a heavy penultimate syllable ineligible for stress.
The End Rule will then assign stress to the antepenultimate syllable. The weakest
E-word edge bias which will reduce the eligibility of a heavy penult to zero is
demonstrated in (35A). Equations for computing the specific values are given in
Appendix B.3.

---

19Foot construction evidently always makes the syllable with primary stress the
head of a foot, avoiding “gaps” on the metrical grid (cf Hayes 1995:34; Prince 1983:33).
(35) Latin Stress Eligibility

A

\[
\begin{array}{c}
\text{Wt} + \text{EE} + \text{WE} = \text{Eligibility} \\
\text{H H H H H} + \text{X X X X X} + \text{X X} = \text{[X X X X X]} \text{X X} \text{[H H H H H H H]} \\
\end{array}
\]

B

\[
\begin{array}{c}
\text{Wt} + \text{EE} + \text{WE} = \text{Eligibility} \\
\text{L L L L} + \text{X X X X} + \text{X X} = \text{[L L L L]} \text{X X} \text{[L L L]} \\
\end{array}
\]

C

\[
\begin{array}{c}
\text{Wt} + \text{EE} + \text{WE} = \text{Eligibility} \\
\text{L L L L} + \text{X X X} + \text{X X} = \text{[L L L L]} \text{X X} \text{[L L L]} \\
\end{array}
\]

D

\[
\begin{array}{c}
\text{Wt} + \text{EE} + \text{WE} = \text{Eligibility} \\
\text{H H H H} + \text{X X X} + \text{X X} = \text{[H H H H H H]} \text{X X} \text{[H H H H]} \\
\end{array}
\]

(A) Negative bias at the end of an E-word renders a heavy penult outside the W-word ineligible, as in \textit{eia-propter}. (B) Positive bias at the end of the W-word makes a light syllable at the end of a W-word eligible when followed by a one-syllable clitic, as in \textit{sceler-que}. (C) When no clitic is present a light penult is ineligible, as in \textit{sceler}. (D) A heavy penult is eligible, as in \textit{potestas}. \textit{EE}=E-word edge bias, \textit{WE}=W-word edge bias, \textit{H}=heavy syllable, \textit{L}=light syllable.

If the E-word were the only relevant domain, the edge bias required for forms like \textit{eia-propter} would produce uniform antepenultimate stress. Words like \textit{sceler-que} demonstrate that Latin stress is not so simple. Instead of being retracted as far back as the antepenultimate syllable, stress here is attracted to the end of the W-word and falls on the penultimate syllable of the word. The attraction of stress to the right edge of a W-word suggests a positive edge bias, increasing the eligibility of syllables near the end of a W-word enough to render them eligible for stress in spite of the negative E-word edge bias. The weakest W-word edge bias which will correctly place stress on a light penult in forms like \textit{sceler-que} is demonstrated in (35B). The eligibility of the penultimate syllable of (35B) is 0.25, just high enough to be distinctly greater than 0.

Having motivated edge biases at the end of both W-word and E-word domains by examining the behavior of stress in forms with clitics, it’s interesting to note that nothing additional need be done to account for the (ante)penultimate pattern of stress in words without clitics. In the absence of a clitic, the edge of the W-word coincides with the edge of the E-word. The E-word edge bias is strong enough to render a light penultimate syllable ineligible for stress, despite the W-word edge bias, as shown in (35C). On the other hand, if the penult is heavy, the weight of the penult combines with the W-word edge bias to overcome the effect of the E-word edge bias. The result is penultimate stress, as in (35D). The eligibility of the heavy penult in (35D) is 0.46.

Discussion

The NMC analysis of Latin enclitic stress makes no reference to metrical constituents, but does adopt the key insight of the Steriade/HK analysis that two morphological domains are relevant for stress assignment in Latin. Stress is repelled away from the end of the E-word, including a clitic if present, and at the same time stress is attracted towards the end of the W-word, whether or not a clitic is attached to it.
In the metrical analyses of Latin reviewed above, structure-preservation is hypothesized to be a universal property of stress rules, so they apply only to unmetrified syllables. In contrast, the positive edge bias at the end of the W-word proposed for the NMC analysis is a language-specific parameter setting. Superficially, this may appear to be a disadvantage for the NMC analysis. If the Latin stress pattern follows directly from general principles of metrical phonology, those principles achieve not just descriptive adequacy, but explanatory force. However, in the Steriade/HK analysis the Latin enclitic stress pattern does not follow directly from the morphological structure of enclitics combined with the stress rules independently motivated by non-enclitic stress. Clitics require a second round of stress assignment which is not independently motivated. HK account for the second round by stipulating that "enclitics are noncyclic suffixes, whereas ordinary suffixes are cyclic" (p. 463). Given their theoretical framework, this is an elegant analysis, but they give no evidence for it aside from the stress pattern it’s intended to account for. Moreover, the purported second round of stress assignment is not the same as the first: whereas stress assignment in nonclitics is quantity sensitive (heavy penults are always stressed), enclitic stress ignores the weight of heavy penults in forms like *ēa-propter*. The point is that neither the metrical analyses nor the NMC analysis derives the stress patterns observed in Latin enclitics directly from general principles. Both analyses combine general principles with language specific parameter settings, and in both analyses some of those parameter settings are motivated solely by the stress facts of Latin enclitics. In this respect the NMC account fares no worse than the metrical account. Moreover, the NMC analysis involves only a single round of stress assignment, and avoids abstract intermediate representations.

Finally, in Steriade’s analysis of Latin enclitic stress, it is absolutely essential that later stress rules respect the structure laid down by earlier rules, or as Halle & Kenstowicz put it, “metrical constituency shields syllables from reapplication of the stress rules” (HK, p. 458). The idea that Latin enclitic stress involves this kind of structure preservation is cited as evidence confirming the reality of metrical constituent structure in general, that is, the idea that stress reflects the organization of syllables into metrical constituents (e.g. HK; Kenstowicz, 1993). If Latin stress is really a matter of nonmetrical prominence, as I argue above, then at least this one argument for the reality of metrical constituents will have to be reconsidered.

3.4. Conclusion
This chapter examined primary stress in three languages where the assignment of primary stress is logically prior to the assignment of secondary stress or metrical feet. The NMC analyses proposed for these languages have a number of advantages over alternative accounts. In Spanish, syllable weight, edge biases, and underlying prominence interact to provide a unified account of primary stress in nouns and verbs. The NMC analysis represents an advance over previous accounts of Spanish in the following respects:
(a) edge biases account for default final/penultimate stress in forms like *doctor*/*doctor-a* without invoking abstract (invisible) class marker vowels, e.g. *doctor-V*.
(b) underlying prominence replaces rule-invoking diacritics in accounting for vowels which idiosyncratically avoid stress, e.g. *granit-ic-o, cocin-a-hig-mos*
(c) the gradience of edge biases accounts for the occurrence of antepenultimate stress rather than preantepenultimate stress in doubly-marked forms like *nume*-
*ic-o*, eliminating the need to stipulate that only the rightmost marked morpheme conditions lexical stress placement
(d) exceptional stress-shifting words like *régenem*/*régemenes* are accounted for via lexical representations rather than mysterious extragrammatical mechanisms
(e) edge biases replace stipulation in accounting for the systematic difference in stress placement observed in noun/verb pairs like *número*/*numéreo*

(f) quantitative interactions between underlying prominence and syllable weight account for lexically-conditioned antepenultimate stress in words like *Frómista* and *acariciemos*, while maintaining the quantity-sensitivity of Spanish stress which militates against antepenultimate stress in words with heavy penults

Polish, like Spanish, exhibits lexically-conditioned deviations from default penultimate stress. Advantages of the NMC analysis of Polish over previous accounts include:

(g) underlying prominence provides a single mechanism which accounts for vowels which idiosyncratically avoid stress, as well as vowels which idiosyncratically attract stress, e.g. *gramára*-a vs. *reće*-ůn

(h) primary stress is assigned without creating abstract metrical feet which must subsequently be deleted

Latin is similar to Spanish, not in terms of lexical stress assignment, but in having nested morphological domains which are relevant for stress assignment. The NMC analysis of Latin achieves the following successes:

(i) edge biases account for stress in cliticized and noncliticized words like *eá-propter, scelerá-que, and scélera*, without requiring two rounds of stress assignment

(h) primary stress is assigned without invoking extrametricality, which would otherwise conflict with evidence from Iambic and Cretic Shortening that word-final syllables are *not* invisible to metrical structure

The success of the NMC model in accounting for morphological and lexical effects on stress in these languages results in large part from the QUANTITATIVE interaction of syllable weight, edge biases, and underlying prominence.
Chapter 4:
The edge-oriented stress systems discussed in Chapters 2 and 3 were analyzed in terms of edge biases and the End Rule, placing stress on the edgemost vowel with stress eligibility greater than zero. There are many stress patterns which cannot be described as assigning stress to the edgemost eligible vowel, including the “12/1L” stress pattern of Malayalam (Hayes, 1995:92) and the “12..89/1L” pattern of Amele (Hayes, 1995:297). In both of these stress systems stress can fall on an initial light syllable, e.g. in words of the form LLLL. The fact that these stress patterns stress can place stress on an initial light syllable suggests that initial light syllables are eligible for stress, i.e. have stress eligibility greater than zero. Nevertheless, an initial light syllable is skipped over if the second syllable is heavy, e.g. in words of the form LLLLLH. If the stress eligibility of a vowel depends only on its own weight and its location relative to edges, the “12/1L” and “12..89/1L” stress patterns and many others do not necessarily assign stress to the edgemost vowel with eligibility greater than zero.

In this Chapter I argue that stress systems vary along a continuum of directional prejudice. The edgemost-eligible-vowel stress systems occupy the extremes of this continuum, placing primary importance on getting stress as close as possible to the left or right edge of the word. Stress systems which do not always place stress on the edgemost eligible vowel occupy intermediate positions on the directional prejudice continuum, where leftmost or rightmost stress may be forgone in order to place stress on a heavy syllable. After motivating the directional prejudice continuum and showing how it can be incorporated into a model of stress assignment based on competition between syllables for stress, I will explore the typology of stress patterns produced by various combinations of a single edge bias and different degrees of directional prejudice. The typology of stress patterns produced by the model will be evaluated against stress patterns actually attested.

4.1. Directional Prejudice

In metrical theory, the End Rule has a binary parameter specifying whether it assigns stress to the LEFTmost or RIGHTmost available syllable. This directional left/right parameter accounts for the distinction between the “1L” stress pattern of Latvian (initial stress) and the “1R” pattern of Weri (final stress). In Chapters 2 and 3 edge biases were invoked to account for deviations from strict initial or final stress, like the penultimate stress of Spanish and Polish or the (ante)penultimate stress of Latin. These languages have a general directional preference to place stress near the end of a word, and the edge bias counteracts that directional preference. The strength of the edge bias determines the distance between stress and the end of a word.

The combination of End Rule and edge biases accounts for a wide range of “bounded” stress systems, in which stress falls within a few syllables of one edge of a word. However, not all stress systems are bounded in this sense. In Agucatec Mayan, for example, primary stress falls on the rightmost heavy syllable, or on the last syllable if there are no heavy syllables in a word; this is a “12..89/1R” stress system. The mirror image “12..89/1L” pattern is observed in Tibetan and a number of other languages. The “12..89/1” patterns of stress cannot be described in terms of an edge bias interacting with the End Rule. However, these stress patterns form a natural continuum with the simple “1L” and “1R” patterns of stress, as illustrated in (1).

In a “1L” language, the preference for stress near the beginning of a word outweighs any tendency for heavy syllables to attract stress. In a “12..89/1L” language, stress falls on a heavy syllable whenever possible, but if there’s a tie between syllables of the same weight, stress will fall on the syllable closer to the beginning of the word. Both
preference ranging from strongly leftward to strongly rightward. Latvian and Weri fall on the extremes of this continuum. Aguacatec is between the extremes, but a little towards one side, with a weak rightward directional prejudice. Tibetan exhibits the mirror image stress pattern of Aguacatec, reflecting a weak leftward directional prejudice.


**Competition for Stress**

Perhaps the most natural way to think about interactions between directional prejudice and syllable weight (or more generally, stress eligibility) is to think of syllables competing for prominence (i.e. stress) on the basis of stress eligibility, with the competition skewed to favor syllables on the left or the right, depending on the directional prejudice parameter. The idea of selecting among competing candidates is central to many models of linguistic and nonlinguistic cognitive processes. The central idea of competition in linguistic processing is that:

mental processing involves a continual decision-making process in which there are many possible candidates competing for each categorization decision and the language user must be able to evaluate the candidacy of each alternative in terms of the cues that support it.

(MacWhinney, 1989:197)

In the Competition Model of the lexicon (MacWhinney, 1989, and elsewhere), words are matched to objects by a competitive feature-matching process, and the candidate with the highest cue strength is chosen. In Optimality Theory, alternative

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1The directional prejudice parameter is similar to the right-left asymmetry parameter, r, employed by Prince (1993) in the analysis of the DLM, except that the right-left asymmetry parameter was used for local competition between adjacent syllables.
phonological or syntactic structures are evaluated against a set of ranked constraints, and
the candidate which best satisfies the highest-ranked constraints is chosen.

In the case of primary stress, the syllables of a word comprise the set of
candidates, one of which is designated the locus of primary stress. The relevant cues for
primary stress assignment include syllable weight, underlying prominence of particular
vowels specified in the lexicon, and the proximity of each syllable to certain
morphological edges. In the NMC model, these cues are represented by weighted
constraints which are added together to determine the stress eligibility of each syllable.
Syllables then compete on the basis of stress eligibility, with the added twist that the
competition is skewed by directional prejudice.

The idea that syllables are active competitors for stress rather than passive
recipients of constituent structure imposed from outside was originally inspired by the
Dynamic Linear Models of Goldsmith and Larson (Goldsmith, 1992, 1993; Larson,
1992). Those models account for rhythmic alternations in prominence by placing each
syllable in competition with adjacent syllables on its left and right. Since the
Goldsmith/Larson models focus on rhythmic prominence relationships between adjacent
syllables, they are fundamentally metrical models of stress. In order to account for the
culminating property of primary stress, it will be necessary to place each syllable into
competition not only with its immediate neighbors, but with all the other syllables of the
word. The winner of the competition will bear the primary stress.

**Formalization of Directional Prejudice**

I will formalize the notion of directional prejudice by defining a directional
prejudice parameter, $\theta$, as the logarithm of the factor by which a syllable on the right is
favored for stress over a syllable to its left with the same stress eligibility. Defined this
way, $\theta$ ranges from negative infinity for infinitely strong rightward prejudice to positive
infinity for infinitely strong leftward prejudice. If the directional prejudice favors
rightward stress over leftward stress by a ratio of 3 to 2, then, by definition, $\theta = \ln \frac{3}{2}$. In
a pairwise competition between syllables $i$ and $j$, with $j$ farther to the right, syllable $i$ is
favored for stress over syllable $j$ just in case $E_i > E_j e^{\theta}$, where $E_i$ and $E_j$ are the stress
eligibilities of $i$ and $j$, respectively. If $\theta$ is positive, $e^{\theta}$ will be greater than 1, conferring
an advantage to the syllable on the right. A syllable farther to the left will win only if it is
heavy enough so that its eligibility $E_j > E_i e^{\theta}$ (recall that in the absence of edge biases
and underlying prominence stress eligibility equals syllable weight). If $\theta$ is negative, $e^{\theta}$
will be between 0 and 1, putting the syllable on the right at a disadvantage.

Directional prejudice affects the competition between two syllables for stress
based on their positions relative to each other, not based on their proximity to an edge. In
a word consisting of 10 light syllables, for example, syllables 1 and 4 are both to the left
of syllable 6. Leftward or rightward directional prejudice will have the same effect on
the competition between syllables 1 and 6 as on the competition between syllables 4 and
6, or between 1 and 4. Similarly, syllables 7 and 10 are both to the right of syllable 6,
and directional prejudice will have the same effect on the competition between syllables
6 and 7 as between syllables 6 and 10, or between 7 and 10.

Again, if the directional prejudice favors rightward stress over leftward stress by a
ratio of 3 to 2, then $e^{\theta} = \frac{3}{2}$ and $\theta = \ln \frac{3}{2}$. Assuming that heavy syllables have twice the
weight of light syllables, as I have throughout, this value of directional prejudice will
produce the Aguacatec “12.89/1R” stress pattern (assuming no edge bias or underlying
prominence). For any two syllables $i$ and $j$, with syllable $j$ to the right of $i$, stress on
syllable $j$ will be favored over stress on $i$ unless the eligibility of $i$ is more than $\frac{3}{2} = 1.5$
times the eligibility of $j$. If the two syllables have the same weight, $L_i \ldots L_j$ or $H_i \ldots H_j$,
or if $i$ is light and $j$ is heavy, $L_i \ldots H_j$, stress on $j$ will be favored over stress on $i$. 
However, if \( i \) is heavy and \( j \) is light, \( H_1 \ldots L_1 \), then stress on \( i \) will be favored over stress on \( j \), because the weight of \( i \) is twice the weight of \( j \), and \( 2 > 1 + \frac{1}{2} \). Here, the weight of syllable \( i \) overcomes the rightward directional prejudice. With \( e^x = \frac{3}{2} \), stress will fall on the rightmost heavy syllable, or on the rightmost syllable if there are no heavy syllables in a word.

Since the competition for stress is based on stress eligibility and directional prejudice, if we know the stress eligibility of any two syllables in a word and we know which of the two is farther to the right, we can determine which one wins in a pairwise competition. Doing all pairwise comparisons between the syllables of a word, there can be only one syllable that wins all of its pairwise competitions, i.e. one syllable which beats all other syllables in the competition for stress.\(^1\) That syllable is favored over each of the other syllables, and wins the competition for stress.

**Pairwise Harmony**

Beginning with the basic inequality that syllable \( i \) beats syllable \( j \) just in case \( E_i > E_j e^x \), we can measure the margin of victory or defeat for \( i \) by simply taking the difference between the quantity on the left side of the inequality and the quantity on the right. The result is \( E_i - E_j e^x \), which will be positive just in case syllable \( i \) is favored over syllable \( j \), and negative if syllable \( j \) is favored over syllable \( i \). It will be convenient to multiply this difference by \( e^{-e^x/2} \) to produce a symmetric pairwise “harmony” score,

\[
M_{ij} = E_i e^{-x/2} - E_j e^{x/2}
\]

(for \( i \) to the left of \( j \)) or \( M_{ij} = E_j e^{-x/2} - E_i e^{x/2} \) (for \( i \) to the right of \( j \)). Again, if the pairwise harmony, \( M_{ij} \), is positive, stress on \( i \) is favored over stress on \( j \).

\(^1\)In a few cases no syllable wins all of its pairwise competitions; in these cases, the global winner is the syllable which comes closest to winning all of its pairwise competitions, as discussed below.

If \( M_{ij} \) is negative, stress on \( j \) is favored over stress on \( i \). The definition of pairwise harmony is symmetric, so that \( M_{ji} = -M_{ij} \).

To illustrate the use of pairwise harmony, suppose \( \theta = \ln \frac{3}{2} \), so that rightward stress is favored over leftward stress by a ratio of 3 to 2, as discussed above. The pairwise harmony values for word forms LHHL and LLLL are laid out in pairwise harmony tables in (2). Each cell of the tables shows the pairwise harmony, \( M_{ij} \), associated with placing stress on syllable \( i \) rather than syllable \( j \). Row and column headings identify the syllable weights for \( i \) and \( j \), respectively.

\[
(2)
\begin{array}{ccccccccc}
A & j & & & & & & & & B \\
& i & LHHL & LHHL & LHHL & LHHL & i & LLLL & LLLL & LLLL & LLLL & LLLL \\
LHHL & -1.63 & -1.63 & -0.41 & & & LLLL & -0.41 & -0.41 & -0.41 & & \\
LHHL & 1.63 & -0.82 & 0.41 & & & LLLL & 0.41 & -0.41 & -0.41 & & \\
\Rightarrow LHHL & 1.63 & 0.82 & 0.41 & & & LLLL & 0.41 & 0.41 & -0.41 & & \\
\Rightarrow LHHL & 0.41 & 0.41 & 0.41 & & & LLLL & 0.41 & 0.41 & 0.41 & \\
\end{array}
\]

The first row of (2A) shows \( M_{12} \), \( M_{13} \) and \( M_{14} \), the pairwise harmony values for syllable 1 versus the other three syllables, in a word of the form LHHL. The way pairwise harmony is defined, a negative value of \( M_{ij} \) means syllable \( j \) is preferred over \( i \) for stress. Since \( M_{12}, M_{13} \) and \( M_{14} \) are all negative in (2A), all the other syllables in a word of the form LHHL are better candidates for stress than is syllable 1, given the rightward prejudice \( \theta = \ln \frac{3}{2} \). This is to be expected, since all other syllables are to the right of syllable 1, and in the word form LHHL all other syllables are at least as heavy as syllable 1.

In the second row of (2A), the first column shows \( M_{21} \), which has a positive value. The positive value indicates that the second syllable of LHHL beats the first
syllable in the competition for stress. If there were only these two syllables in the word, stress would fall on the second syllable. However, there are two additional syllables to the right of syllable 2, and the other two values in the second row of (2A) are negative, indicating that both the third and fourth syllables beat the second syllable.

The pairwise harmony values in the third row of (2A) are all positive, indicating that the third syllable of a word of the form LHHL beats all other syllables in the competition for stress. The pairwise harmony values in the second and third rows of (2A) show that a heavy syllable is always favored over a light syllable, regardless of direction, and between two heavy syllables, the one on the right is favored—in general, the rightmost heavy syllable will win. In a word of all light syllables, the final syllable wins the competition for stress, as indicated by the positive pairwise harmony values in the fourth row of (2B). Again, this is the stress pattern observed in Aguacatec Mayan.

It is easier to visualize the results of a competition for stress if the smallest value from each row of the pairwise harmony table is plotted on a graph. The graphs in (3) identify the weight of each syllable in words of the form LHHL and LLLL, and plot the minimum pairwise harmony for each syllable, i.e. the smallest value from each row of the tables in (2). The stressed syllable is the one whose minimum pairwise harmony is positive, above the horizontal axis.

**Continuous Parameter, Discrete Stress Patterns**

If we hold everything else constant and vary directional prejudice, the value of directional prejudice determines the stress pattern. This is illustrated in (4). Each graph in (4) plots the minimum pairwise harmony value for the syllables in a word of the form LHHL. For a given value of directional prejudice, minimum pairwise harmony values are obtained by calculating a pairwise harmony table as in (2), and taking the minimum value from each row of the table. If the minimum value in row $i$ is positive, syllable $i$ beats all other syllables, winning the competition for stress, and syllable $i$ will be plotted above the horizontal axis in the relevant graph in (4). If the minimum value in row $i$ is negative, syllable $i$ is beat by at least one other syllable, and syllable $i$ will be plotted below the horizontal axis.

The graphs for $\theta=-0.69$, $\theta=0$ and $\theta=0.69$ show two syllables tied in the competition for stress. These values of directional prejudice represent transition points between qualitatively different stress patterns. At these transition points, the smallest change in directional prejudice, or the slightest variation in the strength of any constraint on eligibility, would tip the balance in favor of one syllable or the other. Assuming that the language system is implemented in a noisy biological network of neurons (e.g. the brain), word forms in which two syllables were equally favored for stress would be expected to exhibit variation, with stress appearing freely one or the other (but not both) of the two syllables.
In order to further visualize how the competition for stress varies continuously as a function of directional prejudice, it will be useful to calculate a single measure of the overall harmony of a stress system as a function of directional prejudice. If a pairwise harmony table is computed for a given word form, the minimum pairwise harmony of the winning syllable can be designated the “word harmony” for the corresponding word form. Word harmony measures the margin of victory for the winning syllable of a particular word form. Word harmony will always greater than or equal to zero. In fact, word harmony will be greater than zero except at transition points when two syllables are equally favored for stress. At those points, word harmony will be zero.

For a given value of directional prejudice, we can calculate the word harmony for all possible word forms (in practice, it’s sufficient to do the calculations for a few key word forms). Letting $M_{\min}[\theta]$ and $M_{\max}[\theta]$ be the smallest and largest of the word harmonies for a given value of directional prejudice, I will define “potential harmony” as the difference between the largest and the smallest, divided by the largest:

$$V[\theta] = \frac{M_{\max}[\theta] - M_{\min}[\theta]}{M_{\max}[\theta]}$$

Defined this way, potential harmony will range between 0 and 1.3 Values close to 0 correspond to stress systems in which there’s a very clear winner in the competition for stress, no matter what combination of syllable weights occurs in a word. Potential harmony values close to 1 correspond to stress systems in which some combination of syllable weights results in two syllables of some word form being nearly equally good candidates for stress. Potential harmony is plotted across a range of directional prejudice values in (5). This graph represents the simplest case with no edge bias or underlying prominence. The lower regions of the graph in (5) represent “no contest” situations, while the peaks on the graph represent “tough calls” in deciding which syllable of a word

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3Potential harmony may be negative in degenerate cases with negative word harmony. These cases occur when no syllable beats all the others in the competition for stress. These cases are discussed further in chapter 5.
The directional prejudice continuum is divided into four regions corresponding to different stress patterns. At the two extremes, stress is assigned to the edgemost syllable in a quantity-insensitive fashion. When $|\theta| < \frac{H}{L}$, stress is assigned to the edgemost heavy syllable, or to the edgemost syllable if there are no heavies.

If we begin with a very strong negative (i.e. leftward) directional prejudice and gradually increase it (moving left to right across the graph), at first stress on the initial syllable will be easily more harmonic than stress on any other syllable, regardless of syllable weight. This region of the parameter space produces the “1L” pattern of stress. As the directional prejudice increases, the leftward prejudice becomes less extreme. An initial light syllable will still beat out a heavy syllable elsewhere in the word, but the race for stress gets closer and closer as the directional prejudice becomes less extreme.

There is a critical point at which an initial light syllable and a heavy syllable elsewhere in the word are exactly tied in the competition for stress. As the directional prejudice passes through this critical point, the stress pattern undergoes a qualitative shift. Past the critical point, heavy syllables anywhere in the word are favored over light syllables, producing the “12..89/1L” stress pattern.

When the “12..89/1L” pattern first emerges, a heavy syllable barely wins over a light initial syllable. As the directional prejudice continues to increase and become less extreme, the a heavy syllable more easily beats a light initial syllable. However, as the directional prejudice approaches zero, there is no clear preference between syllables of the same weight. If all the syllables in a word are light, or if there are two or more heavy syllables in a word, it becomes less and less clear which syllable should be stressed as the directional prejudice becomes less biased. As the directional prejudice increases through zero, again there is a qualitative shift in the stress pattern. A weak rightward bias produces the “12..89/1R” stress pattern. Increasing the directional prejudice further again eventually leads to a transition point, beyond which the “1R” stress pattern emerges.

The critical values of $\theta$ which define the crossover points between qualitatively different stress patterns occur when some pattern of syllable weights results in a tie between two syllables, i.e. when the word harmony for some word form is zero. The critical point between “1L” stress and “12..89/1L” stress occurs when the pairwise harmony between a light syllable on the left and a heavy syllable farther to the right is zero, $M_{ij} = E e^{-\theta/2} - E e^{\theta/2} = 0$. In the absence of edge biases or underlying prominence, this reduces to $Le^{-\theta/2} - He^{\theta/2} = 0$, where $L$ and $H$ represent the weight of light and heavy syllables. If heavy syllables weigh twice as much as light syllables, this crossover point is at $\theta = \ln\left(\frac{1}{2}\right) = -0.69$. Symmetrically, the critical point between “1R” stress and “12..89/1R” stress occurs at $\theta = \ln(2) = 0.69$, when the pairwise harmony between a light syllable on the right and a heavy syllable farther to the left is zero. The critical point between “12..89/1L” and “12..89/1R” stress occurs at $\theta = 0$, since negative
values of $\theta$ correspond to leftward directional prejudice and positive values correspond to rightward prejudice. These three critical points divide the directional prejudice continuum into regions corresponding to the four stress patterns of (1).

The potential harmony graph in (5) shows how directional prejudice interacts with syllable weight to produce the typology of four stress patterns laid out in (1). In general, stress eligibility depends not only on syllable weight, but on edge biases and underlying prominence as well. Combining directional prejudice with the full range of constraints on stress eligibility results in a rich variety of possible stress patterns, including the edgemost-eligible vowel stress patterns discussed in Chapters 2 and 3. In those chapters, stress patterns were analyzed in terms of stress eligibility combined with the End Rule, which picked out the edgemost vowel with stress eligibility greater than zero. Since directional prejudice is a generalized form of the End Rule, we can simply replace the End Rule in the analyses of Chapters 2 and 3 with a strong directional prejudice, which will favor stress on the edgemost eligible vowel. A wide variety of other stress patterns are possible as well, and the remainder of this chapter will explore some of those.

4.2 Awadhi—A Case Study

The stress pattern of Awadhi is one of the patterns which requires an edge bias and an intermediate level of directional prejudice. This stress pattern poses a challenge for metrical theories of stress assignment, but is straightforward in the NMC framework. In Awadhi, primary stress falls on the final syllable if a word ends in a LH sequence of syllables; otherwise stress falls on the penult (Hayes, 1995:179). This is a “21/2R” pattern of stress, with stress on the penultimate syllable if it is heavy, otherwise on the final syllable if it is heavy, or else on the penult. Hayes accounts for the stress of Awadhi by building strict bimoraic left-headed feet across the whole word, starting at the right edge; a bimoraic foot consists either of two light syllables, (LL), or a single heavy syllable, (H). The End Rule then designates the head of the rightmost foot the bearer of primary stress, as illustrated in (6a–c). In order to place stress on the penultimate syllable when the last two syllables are both heavy, Hayes suggests that the final syllable is extrametrical if there’s a stress clash between it and the penult, as shown in (6d); stress clash here refers to the configuration of two adjacent stressed syllables.

(6) a. * ... b. * ... c. * ... d. * ... primary stress stress
   - L L - L H ... H L ... H <R>

This analysis succeeds in placing primary stress on the appropriate syllable, but the role of stress clash in this process is somewhat unusual. A clash environment often motivates the application of extra stress rules, but the effect of stress rules conditioned by stress clash is almost always to eliminate the offending clash. In Hayes’ analysis of words ending in a HH sequence, the final syllable must be parsed into a foot in order to create the clash environment which triggers extrametricality, but then making the final syllable extrametrical before applying the End Rule doesn’t eliminate the clash. In effect, stress clash is just used here as a computational device for locating stress on the appropriate syllable. This contrasts with the usual role of clash avoidance as a constraint on output wellformedness.

An NMC analysis of Awadhi can be built around the observations that (1) stress prefers a heavy syllable to a light syllable, (2) among syllables of the same weight, stress prefers the leftmost, and (3) stress is restricted to the last two syllables of the word. The second observation suggests a leftward directional prejudice, but this usually results in stress falling near the beginning of the word rather than near than end. With a leftward directional prejudice, stress can be restricted to the right edge of the word only by a strong positive bias at the end of the word. This word edge bias must be strong enough so that a light penultimate syllable will be preferred for stress over even a heavy syllable.
farther to the left, in spite of the leftward directional prejudice. With an appropriate edge bias (see Appendix C.1 for details), the stress eligibility is calculated as shown in (7).

With a large positive edge bias at the end of a word, the stress eligibility of the final syllable will be considerably greater than the eligibility of any other syllable, regardless of syllable weight. This doesn’t necessarily mean the final syllable receives stress, however. The competition between syllables for stress is skewed by directional

The graph on the left shows the weight of heavy versus light syllables at various positions relative to the end of a word (H=heavy, L=light). The center graph shows the gradient effects of a large positive edge bias, whose strength is 15 times the weight of a light syllable (WE=word edge bias). The combined effect of syllable weight and edge bias is shown in the graph on the right. Although the difference between the eligibility of the final syllable and the penult is greater than the difference between the penult and the antepenult, the ratio of the eligibility of the penult to the antepenult is greater than the ratio of the final to the penult. It is the ratio of stress eligibilities between two syllables which is relevant to the competition for stress.

Each graph shows the smallest pairwise harmony for the last three syllables in a word form, given a final edge bias and leftward directional prejudice appropriate for Awadhi as described in the text (G=15, \( \theta = -0.93 \)). Stress is penultimate unless the word ends in LH, in which case the final syllable wins the competition for stress.

prejudice. With an appropriate amount of leftward prejudice (see Appendix C.1), the penultimate syllable will be able to beat a final syllable of the same weight, despite the edge bias. As long as the leftward prejudice is not too strong, the penultimate syllable will beat a heavy antepenultimate syllable, and a heavy final syllable will be able to beat a light penult. The results of the competition for stress are illustrated in (8), which shows the minimum pairwise harmony for each syllable in word forms ending in LL, LH, HL, and HH. The penultimate syllable wins the competition in all cases except when a word ends in a light followed by a heavy syllable. In that case, the final syllable wins the competition for stress.
4.3. Combinations of Directional Prejudice and a Single Edge Bias

So far I’ve discussed two basic varieties of stress patterns. The typology of edgemost-eligible-syllable patterns discussed in Chapter 2 results from a single edge bias of varying strength interacting with a strong directional prejudice. This typology holds directional prejudice constant and varies the strength of the edge bias. The typology of stress patterns along the directional prejudice continuum discussed earlier in this chapter results from various amounts of directional prejudice in the absence of edge biases. This typology holds the strength of the edge bias constant (at zero), and varies the amount of directional prejudice. The remainder of this chapter will explore the range of stress patterns produced by various combinations of a single edge bias and the directional prejudice continuum by systematically varying both the strength of the edge bias and the amount of directional prejudice. In general, a language might employ edge biases at both ends of a word, but that more complex situation will be left for future exploration.

In exploring the two-dimensional parameter space of edge bias and directional prejudice, I will assume the edge bias is at the left edge of the word. Thus, negative directional prejudice and positive edge bias will favor stress at the beginning of a word, while positive directional prejudice and negative edge bias will favor stress at the end of a word. Compared to the stress patterns produced by an edge bias at the left edge of the word, mirror image stress patterns are produced by associating the edge bias with the right edge instead of the left, and simultaneously reversing the sign of the directional prejudice.

I will also restrict the present analyses to combinations of edge bias and directional prejudice which guarantee a clear winner in the competition for stress. Pairwise competitions for stress are analogous to a round-robin competition in which each competitor is matched against each of the others. If one competitor is undefeated at the end of the tournament, there is a clear, undisputed winner. On the other hand, if no competitor is undefeated, it may be necessary to consider the total number of rounds won by each competitor, or the total points scored, etc. Some combinations of edge bias and directional prejudice create a situation where, for certain word forms, syllable A beats syllable B, syllable B beats syllable C, and syllable C beats syllable A. No syllable beats every other syllable in pairwise competitions, and the minimum pairwise harmony for each syllable is therefore negative. In this situation, it may be reasonable to assign stress to the syllable with the greatest minimum pairwise harmony (see Chapter 5 for additional discussion). For now, I will ignore these degenerate cases in order to analyze the simpler cases first, i.e. the combinations of edge bias and directional prejudice which guarantee that one syllable of every word form wins all its pairwise competitions.

4.3.1. Stress the edgemost eligible syllable

The regions of edge bias and directional prejudice parameter space which produce the edgemost-eligible-syllable typology of stress systems are graphed in (9). These regions produce the “1L”, “12L”, “2L”, “23L”, and “3L” stress patterns. These are the stress systems which can be produced by combining various amounts of edge bias with the End Rule, as discussed in Chapter 2. The SPCs on the graph identify the stress pattern produced by parameter values within the various regions of parameter space. The vertical axis, $G$, represents the strength of the edge bias at the beginning of a word (measured in multiples of the weight of a light syllable). The horizontal axis, $\theta$, represents directional prejudice. Any combination of edge bias and directional prejudice within a labeled region of the graph will produce the stress pattern identified by the label. The parameter regions of (9) are discussed briefly in the following paragraphs.
As shown in the upper left region, a broad range of $G$ and $\theta$ values will produce the “1L” pattern. This stress pattern exhibits “quantity-insensitive” stress on the first syllable. Nearly any nonnegative value of $G$ combined with a negative value of $\theta$ will result in this stress pattern, as long as $G$ and $\theta$ aren’t both too close to zero. Stress on the first syllable is observed in Latvian, Koya, and Garawa (Halle & Vergnaud, 1987:12), and also in Maranungku (Hayes, 1981:87). The mirror image region with the opposite values of $\theta$ and with an edge bias at the end rather than the beginning of the word would produce the mirror image “1R” stress pattern, with stress on the last syllable. The “1R” stress pattern is seen in French (Halle & Vergnaud, 1987:12), Weri (Hayes, 1981:89), and West Greenlandic Eskimo (Hayes, 1981:99).

Even with an edge bias on the left instead of the right, “1R” stress will result if $G$ is negative or at least not very positive. The parameter values which will produce “1R” stress with an edge bias on the left are delimited by the region in the lower right part of the (10). If the directional prejudice is strongly leftward and $G$ is between about −1.5 and −2 times the weight of a light syllable, stress will fall on the first syllable if it’s heavy, otherwise on the second syllable. This produces the “12L” pattern of stress. The negative edge bias reduces the eligibility of the first syllable. The second syllable, which is less affected by the edge bias, wins the competition for stress if the first syllable is light. The “12L” pattern of stress is attested in Hopi, Maidu, Ossetic, Sierra Miwok (Hayes, 1995:261), and Ulwa (McCarthy & Prince, 1990:227). Its mirror image “12R” pattern is seen in Rotumen (Hayes, 1981:104), as well as Fijian, Mam, and Ancient Greek (Hayes, 1995:181).

With a somewhat stronger edge bias, with $G$ between about −2 and −2.2 times the weight of a light syllable, strong leftward directional prejudice will place stress on the second syllable regardless of syllable weight, producing the “2L” pattern of stress.
Second syllable stress is seen in Dakota (Hayes, 1995:267) and Southern Paiute (Hayes, 1981, p. 89). Mirror image stress on the penult is attested in Warao (Hayes, 1981:87), Piro (Hayes, 1995:201), Spanish (Harris, 1983) and Polish (Rubach & Booij, 1985); these last two were, discussed in some detail in Chapter 3.

If $G$ is anywhere between about $-2.25$ and $-5$ times the weight of a light syllable, a strong leftward directional prejudice will place stress on the second syllable if it is heavy, otherwise on the third syllable. This is a “23L” stress pattern. The well-known mirror image “23R” pattern is seen in Classical Latin (Mester, 1994). If $G$ is less than about $-5.5$ times the weight of a light syllable, as shown in the lower left region of (10), a strong leftward directional prejudice will place stress uniformly on the third syllable, regardless of syllable weight. The mirror image “3R” pattern with stress on the antepenultimate syllable is seen in Macedonian, Parnkalla, Kela, Mac, and Cayuvava (Hayes, 1995:205), and also in Paameese (Hayes, p. 178).

The stress patterns “34L”, “4L”, etc. are not attested in real languages. As discussed in Chapter 2, the NMC model can generate edgemost-eligible-syllable stress patterns with stress more than three syllables from the edge of a word, but these stress systems require extremely large negative edge biases (e.g. $G = -55$ for the “34L” pattern). If stronger constraints require greater cognitive effort to represent and process, and take longer to learn, then languages will tend to avoid configurations requiring large constraint weights, including very large negative values of $G$.

4.3.2. Other bounded stress patterns

This section discusses additional regions of the edge bias and directional prejudice parameter space which place stress within a few syllables of the beginning of a word. The parameter regions identified in (10) produce “12/1L”, “21L”, “21/2L”, and “2L” stress patterns. These stress patterns are “bounded” in that they assign stress within a few syllables of the beginning of the word. However, they do not always assign stress to the edgemost vowel with stress eligibility greater than zero. These stress patterns do assign stress to the one vowel which beats all other vowels in a word in a competition for stress. The competition takes stress eligibility and directional prejudice into account, but these factors interact numerically to determine the location of stress.

If the directional prejudice is not very strong, it serves as a tie-breaker between syllables with similar stress eligibility. In that situation, syllable weight and the edge bias are the primary determinants of the stress pattern. A positive initial edge bias will increase the eligibility of syllables close to the beginning of a word, making them more effective competitors for stress. If the positive edge bias is strong enough, stress will fall on a syllable near the beginning of a word, no matter what combination of light and heavy syllables the word has.

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4As discussed in chapter 3, the “23R” pattern of stress in Latin words may result from interactions between a basic “3R” pattern and a positive edge bias at the end of a “host” constituent, which may or may not have a clitic attached.

5I take $G$ to be a measure of the strength of a constraint between a particular edge and stress eligibility, and I assume the implementation of the constraint is essentially analog—it literally takes more “stuff” to impose a stronger constraint. While learning a stress system involves finding an appropriate value for $G$, parameter setting cannot be understood as simply assigning an arbitrary digital value to a variable.
Parameter regions for bounded stress patterns “12/1L”, “21L”, “21/2L”, and “2L”. Region “1L” is also shown. Unlabeled region in lower right is elaborated below. $G$ = strength of edge bias at beginning of word, in multiples of $L$, the weight of a light syllable. $Theta$ = directional prejudice; negative values represent leftward prejudice, positive values represent rightward prejudice.

With only a moderate amount of directional prejudice, a variety of positive edge biases will result in a “12/1L” pattern. This will place stress on the second syllable if a word begins with $LH\ldots$ (underlining the syllable to be stressed). Otherwise, stress will fall on the first syllable, whether the word begins with $L\ldots LH\ldots$ or $HL\ldots$. The edge bias increases the eligibility of the first syllable enough so that, even if the first syllable is light, it’s more harmonic to have stress on the first syllable than on a heavy syllable more than two syllables away from the edge. However, the edge bias also has an effect on the second syllable, making stress on a heavy second syllable more harmonic than stress on an initial light syllable. This “12/1L” stress pattern is attested in Malayalam, Gurkhali, and Yil (1995:93), as well as Tunpisa Shoshone (Hayes, 1995:180). The mirror image “12/1R” pattern is attested in Yapese (Hayes, 1981:109).

If the edge bias is greater than about 5 times the weight of a light syllable, there’s a range of moderate rightward directional prejudice values which will place stress on the second syllable if it’s heavy, or otherwise on the first syllable. This “21L” pattern exhibits stress on the second syllable in words beginning with $HH\ldots$ or $LH\ldots$. Stress falls on the first syllable in words beginning with $HL\ldots$ or $L\ldots$. A positive directional prejudice favors stress on the right, but in this stress region the edge bias is strong enough so that stress is more harmonic on either of the first two syllables than on any syllable farther from the edge. The mirror image of this stress pattern is seen in Sarangani Manobo and Javanese, where syllables with schwa count as light and syllables with other vowels count as heavy. A similar pattern is observed in Malay (Hayes, 1995:263).6

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6Hayes’ analysis of the “21R” stress pattern involves extrametricality of the final foot if there’s a stress clash between the final and the penultimate syllables (i.e. if both are foot heads). As I noted in the discussion of Awadhi above, this is an unusual use of stress clash in the structural description of a rule which doesn’t eliminate the clash.
If \( G \) is greater than about 12.5 times the weight of a light syllable, there’s a range of fairly strong rightward directional prejudice values which will place stress on the second syllable in words beginning with HH, LH, or LL. Stress will fall on the first syllable in words beginning with HL. This is a “21/2L” pattern of stress, the mirror image of the “21/2R” stress pattern of Awadhi discussed above. The “21/2L” stress pattern requires a stronger edge bias than any of the other patterns already discussed. All else being equal, if stronger edge biases really are more difficult than weaker biases, the “21/2” stress patterns should tend to be less common than most other stress patterns. Some analysis and discussion is presented in §4.4 regarding the frequency with which various stress patterns are attested.

Interestingly, a “2L” stress pattern can be produced by a large positive edge bias at the beginning of a word, in conjunction with a fairly strong rightward directional prejudice. This is superficially the same as the “2L” stress pattern discussed in the section on edgemost-eligible stress above. In that section, the “2L” pattern resulted from a NEGATIVE edge bias in combination with a LEFTWARD directional prejudice. There are thus two distinct parameter regions which produce apparently identical stress patterns. However, the stress patterns corresponding with the two “2L” parameter regions are actually different in at least two respects. In the “2L” region of (11), with a positive edge bias and rightward directional prejudice, the initial syllable and the second syllable are very close competitors for stress (see the discussion of “margin of victory” below). In contrast, in the “2L” region of (10), with a negative edge bias and rightward directional prejudice, the second syllable beats the first syllable (and all others, too) by a wide margin. If stress systems with very close competition (ties or near-ties between syllables) are avoided, then the “2L” region with a negative edge bias and leftward prejudice would generally be preferred over the “2L” region with a positive edge bias and rightward prejudice. Secondly, the two regions exhibit different behavior with respect to negative underlying prominence. In the “2L” region of (10), with a negative edge bias, negative underlying prominence associated with the second vowel will shift stress farther from the edge, resulting in lexically-conditioned stress on syllable 3 (cf. discussion of lexical stress in Spanish and Polish in Chapter 3). In contrast, within the “2L” region of (11), with a positive edge bias, [-UP] on the second syllable will shift stress CLOSER to the edge, resulting in stress on the first syllable. Thus, the location of lexical stress may distinguish between the different “2L” regions of parameter space, providing the occurrence of lexical stress can be unambiguously attributed to the second vowel of a word.

In addition to the parameter regions shown in (11), there’s an infinite series of parameter regions for bounded stress patterns, occupying a very narrow, finite area just below the “12/1L” region. This series of parameter regions produces a series of “12...n/1L” stress patterns, where \( n \) takes on the values 3, 4, 5,... These patterns assign stress within an \( n \)-syllable window at the beginning of a word. Within that window, stress falls on the leftmost heavy syllable, or on the first syllable of the word if there are no heavy syllables within the \( n \)-syllable window. The entire series of parameter regions fills a narrow wedge bordering the lower left edge of the “12/1L” region, in the approximate range \(-0.69 < \theta < 0\). The widest part of this wedge occurs at \( \theta = 0 \), where some variant of bounded “12...n/1L” stress will be produced by any edge bias in the approximate interval 1.0 < |\( \theta \L_2 | < 1.02\).

The first, and widest, of these stress regions produces a “123/1L” stress pattern, with stress assigned within a 3-syllable window. The “123/1L” stress pattern produces word forms like HHH, HHH, HLH, and LLL. Stress never appears more than three syllables from the beginning of a word. A pattern similar to the mirror image of this stress pattern is attested in Pirahã (Everett & Everett, 1984), except that Pirahã distinguishes five degrees of syllable weight rather than just the two assumed in the present analysis (cf. Chapter 1). Pirahã has a “123/123/123/1R” pattern of stress.
Other members of the “12...n/1L” series occupy increasingly narrow regions immediately below the “123/1L” region, with the width of the regions becoming infinitesimally small as the width of the stress window increases without bound. Thus, in principle it’s possible to produce a “1234/1L” pattern of stress, etc. To my knowledge such stress patterns are unattested, and the ability of the NMC theory to produce these stress patterns might therefore be considered a weakness of NMC theory. However, the range of parameter values which will result in these patterns is extremely small and gets exponentially smaller as n increases. Ranges of G values which will produce “12/1L”, “123/1L”, “1234/1L”, and “12345/1L” stress patterns are given in (11). The calculation of these values assumes the directional prejudice is zero, since this maximizes the range of G values for a given “12..n/1L” stress region (see appendix C.3 for relevant equations).

(11) Edge Bias Values for “12..n/1L” Stress Pattern

<table>
<thead>
<tr>
<th>n</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Upper – Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.0186574</td>
<td>1.5819767</td>
<td>0.5633193</td>
</tr>
<tr>
<td>3</td>
<td>1.0001234</td>
<td>1.0186574</td>
<td>0.018539</td>
</tr>
<tr>
<td>4</td>
<td>1.0000001</td>
<td>1.0001234</td>
<td>0.0001233</td>
</tr>
<tr>
<td>5</td>
<td>1.0000000</td>
<td>1.0000001</td>
<td>0.0000001</td>
</tr>
</tbody>
</table>

In order to produce the “123/1L” pattern, G must be set within a range whose width is about 2% of the weight of a light syllable. To produce a “1234/1” pattern, which violates the cross-linguistic three-syllable stress window, the value of G must be set within a range whose width is about ±0.01% of the weight of a light syllable. Such precision in parameter setting is not necessarily ruled out by principles of linguistic competence. The NMC model therefore appears to predict the possibility of stress patterns which do not, in fact, seem to occur in natural language. However, models of linguistic PERFORMANCE which account for slips of the tongue and other types of speech errors typically assume the language system is plagued by a certain level of random variation or “noise” (e.g. Dell, Juliano & Govindjee, 1992; Stemberger, 1985, 1992; Wheeler & Touretzkey 1995). As Brian MacWhinney put it, “there is always some variation in the [language processing] system which can occasionally lead to error” (MacWhinney, 1989:202). With a given level of noise in the system, it will be increasingly difficult to learn patterns which require very accurate parameter settings, because the noise will swamp the signal. Instead of getting a consistent stress pattern, the location of stress actually produced will vary apparently at random between the target pattern and other stress patterns with nearby parameter values.

The amount of variability in stress placement (i.e. the number of errors) will be inversely related to the width of the parameter region for a target stress pattern. For example, suppose the variability of a single parameter (e.g. the edge bias G) is normally distributed with a standard deviation of 0.1. The frequency with which the variability of that parameter will cause an error depends on the precision with which that parameter must be set (i.e. the width of the parameter region for the target stress pattern). The percentage of errors expected is given in (12) for several different levels of required precision. If the parameter region is wider than the standard deviation of the variability, errors will be relatively infrequent. If the width of the parameter region is about the same as, or narrower than, the standard deviation of variability, errors will be exceedingly common.

Unattestedness is based primarily on Halle & Vergnaud ([, 1987 #11]) and Hayes ([, 1995 #122]), as discussed in §4.4 and Appendix D.
In short, the absence of “1234/1” patterns, etc., among the attested human languages may be due to performance factors rather than an outright structural limitation imposed by principles of linguistic competence. If this is the case, then it’s a strength rather than a liability of the NMC theory that it is compatible with these unattested patterns. The NMC is a model of linguistic competence, and a model of competence should not duplicate or stipulate facts which would fall out of a complementary model of performance. The relationship between performance factors and likely stress patterns is discussed further in §4.4.

4.3.3. Unbounded leftmost heavy stress patterns

Stress is not always confined to a narrow window at one edge of a word. This section discusses stress patterns which generally assign stress to the leftmost heavy syllable (possibly excluding syllables near the edge of a word). All of these stress patterns involve weak leftward directional prejudice, with the edge bias either negative or at least not too positive. Under these conditions, syllable weight dominates directional prejudice, so stress will generally seek out the leftmost syllable in a word, no matter how far the syllable is from the beginning of a word. In order to show the relevant stress

<table>
<thead>
<tr>
<th>Required Precision</th>
<th>% Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.5</td>
<td>&lt; 0.0001%</td>
</tr>
<tr>
<td>±0.25</td>
<td>1.2%</td>
</tr>
<tr>
<td>±0.1</td>
<td>32%</td>
</tr>
<tr>
<td>±0.01</td>
<td>92%</td>
</tr>
</tbody>
</table>

Expected frequency with which a noisy parameter value will deviate more than a given amount from the average value for that parameter. Assumes noise is normally distributed with a standard deviation of 0.1.

regions more clearly, they will be graphed in two groups. The first group, shown in (13), identifies parameter regions for “12..89/1L”, “12..89/2L”, “23..891/2L”, “23..891/3L”, “34..8921/3L” and “34..8921/4L” stress patterns. The second group, shown in (14), identifies parameter regions for “23..89/3L”, “34..892/3L”, “34..892/4L”, “34..89/3L”, and “34..89/4L” stress patterns. The second group involves stronger negative edge bias values than the first group.

If G is close to zero (little or no edge bias at the beginning of a word), a wide range of leftward directional prejudice values will place stress on the leftmost heavy syllable in a word, L, HH..L, or on the first syllable if there are no heavy syllables, L..L. This is the “12..89/1L” pattern discussed above in the typology of stress patterns across the directional prejudice continuum. The parameter region which produces this pattern is shown just above the center of (13). It lies just below the infinite series of “12..n/1L” patterns discussed in the preceding section. The “12..89/1L” stress pattern is attested in Khalkha Mongolian and Yana (Hayes, 1981). It’s also attributed to Serbo-Croatian and Lithuanian, where the heavy/light distinction is determined by high versus low tones (Hayes, 1995:279). A similar pattern is seen in Catalan, where heavy syllables are marked lexically (Hayes, 1981:100); in the NMC framework, lexically-marked “heavy” syllables would carry [+UP]. The basic “12..89/1L” pattern is also seen in Russian, with additional complexities introduced by lexical stress and segmental processes (Idsardi, 1992).
Parameter regions for unbounded leftmost heavy stress patterns “12..89/1L”, “12..89/2L”, “23..891/2L”, “34..8921/3L”, and “34..8921/4L”. Regions “1L” and “12/1L” are also shown. Unlabeled regions below and to the right of those shown are elaborated below. $G =$ strength of edge bias at beginning of word, in multiples of $L$, the weight of a light syllable. $\theta =$ directional prejudice; negative values represent leftward prejudice.

With a somewhat stronger negative edge bias, a slightly different stress pattern emerges which places stress on the second syllable rather than the first in words of all light syllables, LLL...L. This is the “12..89/2L” pattern, which has been attributed to Khalkha Mongolian (Stuart, 1957, cited in Goldsmith, 1990:343, fn. 9).

With an even stronger negative edge bias, a variety of stress patterns emerge from interactions between the edge bias and directional prejudice, including “23..891/2L”, “23..891/3L”, “34..8921/3L”, and “34..8921/4L”. I have not yet found any of these patterns documented in the literature on stress systems. An analysis of discrepancies between theoretically possible and actually attested stress patterns is offered in §4.4, where I suggest that performance factors may account for the unattestedness of these stress systems. Although performance factors might render these stress patterns unlikely or impossible, the NMC model makes the prediction that these stress patterns represent legitimate configurations of linguistic competence. A language with one of these stress patterns would therefore constitute strong evidence in support of the NMC model.

The “23..891/2L” pattern places stress on the leftmost heavy syllable to the right of the first syllable, HL...HHL. If there are no heavy syllables to the right of the first syllable, stress will fall on the first syllable if it’s heavy, HHL, otherwise on the second syllable, LL...L. In a metrical framework, a “23..891/2L” pattern might be analyzed as a case of mora extrametricality. If the first mora is extrametrical, the first syllable will behave as if it’s weight were reduced by one notch. A heavy first syllable will act like a light syllable for purposes of stress assignment and will be passed over by the process which assigns stress to the leftmost acting heavy syllable. A light (monomoraic) first

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6Goldsmith notes that there are conflicting descriptions of Khalkha Mongolian stress corresponding to “12..89/1L” and “12..89/2L”. See Appendix D.1 for references.
syllable will be completely invisible to the stress process, which can therefore simply assign stress to the leftmost available syllable at the highest level of syllable weight.

The “23..891/3L” pattern also places stress on the leftmost heavy syllable to the right of the first syllable, HL..HH.L, or on an initial heavy syllable if there are no other heavy syllables, HI..L. The “23..891/3L” pattern differs from the “23..891/2L” pattern, however, in placing stress on the third rather than the second syllable in words of all light syllables, LL.L.L.

Within a triangular region with directional prejudice weakly leftward and \( G \) between zero and about 1.2 times the weight of a light syllable, stress will fall on the first heavy syllable to the right of the first two syllables, HHL..HH.L. If there are no heavy syllables to the right of the first two syllables, stress will fall on the second syllable if it’s heavy, HH.L.L, or else on the first syllable if it’s heavy, HI..L.L. If all the syllables in a word are light, stress will fall on the third syllable, LL.L.L. This is the “34..892/3L” pattern identified in (13). There is an infinite series of variations of this stress pattern, “34..892/1L”, with stress farther and farther to the right in words with no heavy syllables, including the narrow “34..892/4L” region shown in (13). The range of directional prejudice values which will produce these variations rapidly dwindles as \( n \) increases. As with the “12..n/1” patterns discussed earlier, the “34..892/n” patterns are expected to be uncommon because even small amounts of variability in parameter settings would make it difficult to accurately produce these stress patterns.

A variety of stress regions with even stronger negative edge biases are shown in (14), including the “23..89/3L”, “34..892/3L”, “34..892/4L”, “34..89/3L” and “34..89/4L” patterns. In all of these stress regions, the negative edge bias is strong enough that the first syllable is never stressed, even if it’s the only heavy syllable in a word. Under these conditions, the first syllable appears to be extrametrical. Again, to my knowledge none of these stress patterns are attested. The analysis of harmony contrast in §4.4 suggests that “34..892/3” and “34..89/3” should be a viable stress patterns. In other words, the NMC model predicts the possibility of these patterns of stress, though I have not yet seen them attested. The other stress regions of (14) are considerably poorer in terms of the harmony contrast measure discussed in §4.4, so they are expected to be either unattested or at least relatively uncommon.

The triangular region of parameter values shown near the upper left corner of (14) produces a “23..89/3L” pattern. Stress falls on the leftmost heavy syllable to the right of the first syllable, XL..HH.L (where X represents either H or L), or on the third syllable if there are no heavy syllables to the right of the first, XL.L.L.

With either a stronger negative edge bias or a weaker directional prejudice, stress will fall on the first heavy syllable to the right of the first two syllables, XHL..HH.L. If there are no heavy syllables to the right of the first two, stress will fall on the second syllable if it’s heavy, XH.L.L, or else on the third syllable, XL.L.L. This is the “34..89/3L” pattern of stress, one which is predicted to occur (see discussion in §4.4) though I cannot yet cite an example of it.

With an even stronger negative edge bias, stress will again fall on the first heavy syllable to the right of the first two syllables, XXL..HH.L. If there are no heavy syllables to the right of the first two syllables, stress will fall on the third syllable, XXL.L.L. The upper part of the parameter space for this “34..89/3L” pattern is shown in the lower part of (14). In this stress pattern the first two syllables of the word are never stressed, and they might both be described as being “extrametrical”. This is another stress pattern predicted by the NMC model (see §4.4), but it is not attested in the sources used to compile the stress system indexes in Appendix D.
Parameter regions for unbounded leftmost heavy stress patterns “23..89/3L”, “34..89/3L”, “34..892/3L”, and “34..89/4L”. Regions “23..891/3L”, “34..8921/3L”, “23L”, “3L” are also shown. Unlabeled region to the right of those shown are elaborated below. \( G \) = strength of edge bias at beginning of word, in multiples of \( L \), the weight of a light syllable. \( \text{Theta} \) = directional prejudice; negative values represent leftward prejudice.

Once again, there are variations of the last two stress patterns (“34..892/3L” and “34..89/3L”) with stress farther and farther to the right in words with no heavy syllables, i.e. “34..892/nL” and “34..89/nL” stress patterns. These variations involve narrow ranges of directional prejudice. Parameter regions for “34..892/4L” and “34..89/4L” patterns are shown near the right edge of (14). In addition to the narrowness of these stress regions, they involve directional prejudice values close to zero. When the directional prejudice is close to zero, all pairwise harmony values (except those involving the syllables most affected by the edge bias) will be very close to zero. In effect, it becomes less and less clear that one syllable is preferred over the others in the competition for stress. As I argue in §4.4, languages might be expected to avoid stress systems which require arbitrarily fine distinctions to be made in deciding which syllable is the maximally harmonic location for stress. Thus, there’s reason to expect that “34..892/n” and “34..89/n” stress patterns (with \( n > 3 \)) would be uncommon or impossible, even though their existence is not specifically ruled out by the NMC model.

4.3.4. Unbounded rightmost heavy stress patterns

A positive directional prejudice will tip the balance in favor of syllables farther to the right rather than the left. This section discusses stress patterns which assign stress to the rightmost heavy syllable, with variations determined primarily by the amount of initial edge bias. These stress patterns include “12..89R”, “12..89R1R”, “12..78/1R”, “12..67/1R”, “198..32/1L”, “1298..43/1L”. Only the first two of these stress regions correspond to attested stress patterns, though the harmony contrast analysis of §4.4 predicts the viability of “12..78/1” and “12..67/1” patterns, as well.

If the directional prejudice is moderately rightward and the edge bias at the beginning of the word is either negative or at least not too positive, then stress will tend to seek out the rightmost heavy syllable in a word, no matter how far it is from the edges.
of the word. With no edge bias at all, stress will fall on the rightmost heavy syllable, L.HH.L, or on the last syllable if there are no heavy syllables in a word L.L. This is the mirror image of the “12..89/1L” pattern discussed above. The parameter region for the “12..89/1R” pattern is shown just above the center of (15). This pattern of stress is attested in Aguacatec Mayan and Golin (Hayes, 1981). In Golin, the heavy/light distinction is determined by high versus low tones, respectively.

There’s a thin band of positive G values shown above the “12..89/1R” region in (15) which result in stress falling on the first syllable rather than the last syllable if there are no heavy syllables in a word, L.L. If there are any heavy syllables, the rightmost heavy will receive stress, L.HH.L. This “12..89R” pattern of stress is attested in Eastern Cheremis, Huasteco and Chavash; the mirror image pattern is seen in Komi (Hayes, 1981:96). The “12..89” pattern of stress is surprisingly common in light of the narrowness of the corresponding stress region in (15). This could be an indication that the NMC model is in need of refinement. Assuming a larger difference between the weight of heavy and light syllables, for example, would make the “12..89R” parameter region wider. The width of this parameter region is also dependent on the parameter g, which determines how fast the efficacy of an edge bias drops off as the distance from the edge increases (cf. §2.3); a smaller value of g would result in narrower edge biases and a wider “12..89R” parameter region.

Parameter regions for unbounded rightmost heavy stress patterns “12..89”, “12..89/1R”, “12..78/1R”, “12..67/1R”, “198..32/1L”, “1298..43/1L”. Regions “1L”, “12/1”, “12..89/1L”, “34..8921/4L”, “34..892/4L”, and “1R” are also shown. G = strength of edge bias at beginning of word. Theta = directional prejudice; positive values represent rightward prejudice.
If the initial edge bias is somewhat larger, the eligibility of the first syllable is enhanced enough so that it will take precedence over other syllables of the same weight. Stress will fall on the first syllable if it’s heavy, H.H, or if there are no heavy syllables in the word, L.L. Otherwise stress falls on the rightmost heavy syllable, L..HH..L.. The region of parameter values which will produce this “198..32/1L” pattern is shown above the “12..89R” region of (15). If the first syllable of a word is light, this stress pattern involves stress on the rightmost heavy syllable. However, the SPC for this pattern is oriented from the beginning of the word rather than from the end, because the highest priority syllable is the first one. This stress pattern is evidently unattested. The harmony contrast analysis of §4.4 suggests this pattern is likely to be uncommon because these parameter settings produce a fairly small margin of victory for the winning syllable in the competition for stress.

If the edge bias is a little larger and the directional prejudice is a little weaker, stress will again fall on the first syllable if it’s heavy, H.HH..L, or if there are no heavy syllables in the word, L..L. If the first syllable is light but the second is heavy, stress will fall on the second syllable, LH.HH..L. If neither of the first two syllables is heavy, stress will fall on the rightmost heavy syllable in the word, LL..HH..L. This is a “1298..43/1L” pattern of stress. Again, this pattern of stress is unattested. The harmony contrast analysis of §4.4 suggests this stress pattern is only slightly more viable than the “198..32/1L” pattern discussed above.

If the edge bias is increased any more, the stress eligibility of the first two syllables is so great that stress will always fall on the first or second syllable in spite of the small rightward directional prejudice. The resulting stress patterns were discussed above in the sections on bounded stress patterns.

With a negative initial edge bias rather than positive, the eligibility of the first syllable can be reduced enough so that it will not be stressed even if it’s the only heavy syllable in the word. The result is apparent first-syllable extrametricality, with stress on the rightmost noninitial heavy syllable, X..HH..L, or on the last syllable if there are no heavies to the right of the first syllable, XL..L. The parameter region for this “12..78/1R” pattern is shown below the region for “12..89/1R” in (15). Recall that the “1” in a right-oriented SPC like “12..78/1R” refers to the last syllable of the word and not the first syllable. The apparent extrametricality of the first syllable here is, of course, just the result of an edge bias imposing a constraint against stress close to the beginning of the word. The “12..78/1R” pattern of stress is evidently not attested, though the NMC model does predict its possibility. The possibility of this stress pattern is also predicted by metrical theory—it could be accommodated within the theory proposed by Hayes (1995), for example, by combining initial-syllable extrametricality with prominence-based stress assignment.

If the negative edge bias is even stronger, the second syllable as well as the first will be passed over for stress assignment, rendering a “12..67/1R” pattern of stress. Stress will fall on the rightmost heavy syllable to the right of the first two syllables, XX..HH..L, or on the last syllable if there are no heavy syllables to the right of the first two syllables, XXL..L. Like the preceding stress pattern, the possibility of a “12..67/1” pattern is predicted by the NMC, but is evidently not attested.

In principle, stress systems like “12..45/1R” can be generated by the NMC model, with three or more syllables at the beginning of the word being passed over for stress assignment. The parameter space for such stress systems is sandwiched in between the region for “12..67/1R” and the region for “1R”. Such stress patterns are somewhat “unnatural” in exhibiting unusually long-range edge effects. However, these stress patterns involve very large negative G values and/or very precise settings of directional prejudice within a very narrow range of values. The apparent nonexistence of such patterns among human languages might be explained by supposing that very large edge
biases and very exact directional prejudice values are difficult to master. I will return to this point in the following section.

4.4. Evaluation

The two-dimensional parameter space characterized by directional prejudice and a word-initial edge bias contains the 28 stress regions identified in (9), (10), (13), (14) and (15). All 28 regions are shown together in (16). As noted in the previous section, in addition to these 28 parameter regions, there are an infinite number of distinct stress patterns which can be produced by varying the strength of a single edge bias and the amount of directional prejudice. A relatively small (and finite) number of these stress patterns are actually attested in some language. The discussion below examines the parameters of the NMC model and the margin of victory between syllables in the competition for stress, and argues that all but a few of the stress patterns produced by the model are likely to be excluded from actual languages by performance factors.

\[ G = \text{strength of edge bias at beginning of word.} \]
\[ \Theta = \text{directional prejudice.} \]

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9I include in this count the "123/1L" stress region which was discussed but not actually shown because it is extremely narrow.
In §4.3, I suggested that performance factors may render certain theoretically possible stress patterns practically unusable. Specifically, I suggest that: (1) there is a limit on the precision with which a language user can control the numerical parameters which determine the location of stress (e.g. the strength of an edge bias or the amount of directional prejudice); (2) there is an increasing cost associated with stronger constraints (i.e. larger positive or negative parameter values); and (3) it is more difficult to determine the winner of a competition when the competition is very close than when the margin of victory is relatively large. When these factors are taken into account, the NMC model does a remarkable job of distinguishing between stress patterns which actually are attested and stress patterns which are not attested. ¹⁰

In principle, there are an infinite number of distinct stress patterns defined by the two-dimensional parameter space of directional prejudice and a single edge bias at the beginning of a word. However, almost all of the infinitely many theoretically possible stress patterns occupy very narrow regions of parameter space, including the “12...n/1”, “34...892/n” and “34...89/n” stress patterns (with n > 3). These patterns can only be produced if the parameters of the model are set with very high precision. Such stress patterns are unlikely to be observed in actual languages because variability in the language processing system will result in noisy parameter values, and noisy parameter values will result in unintended variation in the location of stress (cf. figure 12). If a language learner is confronted with a high degree of variability and relatively few good examples of the target stress pattern, the learner is unlikely to successfully acquire the target stress pattern. In that case, the stress pattern will change from one generation of language users to the next. Stress patterns which require extremely precise parameter settings are expected to be inherently unstable diachronically, and are therefore likely to be relatively uncommon. If they do occur, they are expected to exhibit variability in stress placement (see Hammond, 1994 for one example of variable stress).

In addition to limiting the effective precision with which parameter values can be set, it is reasonable to suppose there is practical upper limit on the magnitude of parameter values as well. This follows from the plausible assumption that greater cognitive resources are required for stronger (positive or negative) constraints—an assumption which is implicit in many connectionist models of learning, for example. The stress regions shown in (16) are all produced by directional prejudice values in the range ±2, and edge bias values in the range ±15. Also, if constraints are initially very weak and become incrementally stronger as learning proceeds (until reaching the strength required by the target stress system), then it will take longer to acquire stronger constraints. Performance factors thus constrain the set of possible (or at least likely) stress patterns by imposing practical limits on the magnitude and precision of constraint weights.

If we assume there is a finite limit on the magnitude of the edge bias, and also a limit to the precision with which different values of parameter values can be distinguished, then we can probably rule out most stress regions other than the 28 shown in (16) as being unlikely to be attested. In addition, the “1L” and “1R” regions of (16) are really mirror image variants of each other, as are the “12..89/1L” and “12..89/1R” regions. This brings the number of distinct stress regions under consideration to 26. Do all 26 of these stress regions have counterparts in actually attested stress patterns? The short answer is no, some are attested and some are not, as noted in §4.3. However, all stress regions are not created equal. In some stress regions, one syllable beats all other

¹⁰The analysis here is restricted to stress patterns which may be produced by the NMC model with a single edge bias. The question addressed is therefore, “How many of the stress patterns produced by this reduced model are actually attested?” I leave for the future the question, “How many actually occurring stress patterns can be accounted for by some combination of NMC parameters?”
syllables by a wide margin in the competition for stress. In other stress regions the
competition is closer, and the margin of victory for the winning syllable is very small.

It’s a well-known axiom of psychology that substitution errors are more common
between similar items than between dissimilar items. As Amos Tversky put it, “the more
similar the stimuli, the more likely they are to be confused” (Tversky, 1977:335). In the
NMC model, primary stress assignment involves a choice between competing syllables
based on pairwise harmony. If the top two syllables in the competition have nearly
identical minimum pairwise harmony values, it will be difficult to decide which one is
truly greater. Variability in the system will obscure the “true” values, and the syllable
with a theoretically smaller minimum pairwise harmony may be chosen by mistake. The
frequency of such errors will increase as the contrast between the top two syllables
decreases. This line of reasoning suggests that stress regions in which one syllable wins
by a larger margin should tend to be more common than stress regions in which the
margin of victory is relatively small.

To test this hypothesis, a harmony contrast score was computed for each of the 26
parameter regions under consideration. The harmony contrast score for each parameter
region was based on the word form (i.e. the sequence of light and heavy syllables) which
resulted in the closest competition for stress within that parameter region. Given that
worst case word form, the harmony contrast score was computed by finding the values
for $G$ and $\theta$ which maximize the margin of victory for the winning syllable.$^{11}$ The
harmony contrast score was determined by taking the difference between the minimum
pairwise harmony values for the top two syllables (cf. §4.1). The 26 stress regions under

$^{11}$In some stress regions the margin of victory monotonically increases as $G$
and/or $\theta$ approach positive or negative infinity. For these stress regions harmony contrast
was computed based on reasonably small $G$ and $\theta$ parameter values, shown in (16).

consideration are listed in (18), in order of decreasing harmony contrast. The parameter
values at which the harmony contrast scores were computed are also given for each stress
region.

I constructed a list of “attested” primary stress systems based on a systematic
search through Halle & Vergnaud (1987) and Hayes (1995), with additional stress
patterns gathered less systematically from a number of other sources (prior to the
calculation of harmony contrast). The entire list of attested primary stress systems is
given in Appendices D.1 and D.2, and includes 144 languages. This list is no doubt
incomplete, but should represent a reasonably unbiased sample for evaluating the NMC
model.

If stress regions with very close competitions for stress are problematic, we
expect numerous languages to exhibit the stress patterns corresponding to larger harmony
contrast scores, and very few languages to exhibit the stress patterns corresponding to
lower harmony contrast scores. Comparison between the 26 parameter regions under
consideration and the list of attested stress systems reveals that 11 of the 26 parameter
regions correspond to stress patterns which are attested, and 15 correspond to patterns
which are unattested. The rightmost column of (18) lists the number of languages found
to correspond with each of the 26 parameter regions or their mirror image counterparts.
All languages exhibiting “2” patterns have been attributed to the “2” parameter region
with a negative edge bias, i.e. the “2” region shown in (9). The evidence from lexical
stress in Spanish and Polish discussed in chapter suggest these “2” languages, at least,
involve a negative bias at the edge of the word. In the absence of any clear cases of “2”
stress resulting from a positive edge bias, I tentatively categorize the “2” region shown in
(10) as unattested. This treatment of “2” patterns is disadvantageous for the NMC model,
and may be overly pessimistic. Finally, languages with more than two levels of syllable
weight were not included in the count of languages. The “123/123/123/123” pattern of
Pirahã, for example, is not counted in (18). Neither is the “12..89/12..89/1” pattern of Maori nor the “23..891/23..891/2” pattern of Hindi.

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<th>(\theta)</th>
<th>(G)</th>
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<th>Rank</th>
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<tr>
<td>21</td>
<td>0.88</td>
<td>5.75</td>
<td>0.77</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>34..89/3</td>
<td>-0.45</td>
<td>-4.60</td>
<td>0.69</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>21/2</td>
<td>0.92</td>
<td>14.12</td>
<td>0.63</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>12/1</td>
<td>0.11</td>
<td>1.59</td>
<td>0.58</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>12..78/1</td>
<td>0.27</td>
<td>-1.00</td>
<td>0.55</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>23..89/3</td>
<td>-0.50</td>
<td>-1.63</td>
<td>0.51</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>12..89/2</td>
<td>-0.55</td>
<td>-0.73</td>
<td>0.42</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>1298..43/1</td>
<td>0.10</td>
<td>1.04</td>
<td>0.33</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>23..891/3</td>
<td>-0.32</td>
<td>-1.15</td>
<td>0.32</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>34..89/4</td>
<td>-0.28</td>
<td>-20.00</td>
<td>0.28</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>34..8921/3</td>
<td>-0.14</td>
<td>-1.02</td>
<td>0.24</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>198..32/1</td>
<td>0.30</td>
<td>1.61</td>
<td>0.22</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>23..891/2</td>
<td>-0.73</td>
<td>-1.23</td>
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<td>22</td>
<td></td>
</tr>
<tr>
<td>12..89</td>
<td>0.34</td>
<td>0.99</td>
<td>0.13</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>34..892/4</td>
<td>-0.03</td>
<td>-2.76</td>
<td>0.03</td>
<td>24</td>
<td></td>
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<tr>
<td>123/1</td>
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<td>1.01</td>
<td>0.02</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>34..8921/4</td>
<td>-0.01</td>
<td>-1.01</td>
<td>0.01</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Parameter regions sorted in order of decreasing harmony contrast. A large contrast means that the winning syllable is decisively favored over the next-best syllable. A contrast score close to zero means that stress on the winning syllable is only marginally more harmonic than stress on the second place syllable. The rightmost column is left blank for parameter regions which are unattested. \(\theta\) = directional prejudice, \(G\) = edge bias strength.
There is a clear correlation between larger contrast scores and attestedness. Of the 13 stress regions in the lower half of (18), only 2 are attested. Of the 13 stress regions in the upper half of (18), 9 are attested and 4 are unattested. Stress patterns with low harmony contrast scores appear to be uncommon. To confirm that the higher contrast values of the model really do correspond more to attested stress patterns than to unattested ones, each stress pattern listed in (18) was categorized as attested or unattested depending on whether or not it is attributed to at least one language in the literature on which this analysis is based. A ranking was established between the 26 stress patterns based on the harmony contrast scores, and a statistical analysis was performed using Wilcoxon’s Rank-Sum test. The number of attested versus unattested stress patterns and the sum of ranks for each group are shown in (19). Wilcoxon’s one-tailed Rank-Sum test was significant (WS(11,15)=109, p < 0.025). This result is consistent with the hypothesis that languages prefer stress patterns in which one syllable is a clear victor over other syllables in the competition for stress.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Patterns</th>
<th>Sum of Ranks</th>
<th>Expected Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attested</td>
<td>11</td>
<td>109</td>
<td>148</td>
</tr>
<tr>
<td>Unattested</td>
<td>15</td>
<td>338</td>
<td>202</td>
</tr>
</tbody>
</table>

Although most of the high contrast stress patterns are attested and most of the low contrast patterns are not attested, there is not a strict dichotomy, with all stress patterns above a certain threshold of harmony contrast being attested, and all stress patterns below the threshold being unattested. Neither is there a perfect correlation between increasing harmony contrast and the number of languages exhibiting a particular stress pattern. These aspects of the data deserve comment.

First, there’s no reason to expect a strict dichotomy, with all stress patterns above a certain threshold of harmony contrast being attested, and all stress patterns below the threshold being unattested. Harmony contrast scores are distributed along a continuum. While it is natural to expect stress patterns with very low contrast scores to be relatively uncommon, it is not at all clear that we can identify a threshold such that all possible stress patterns will have contrast scores above the threshold. Instead, stress patterns with lower contrast plausibly require more effort than patterns with higher contrast and are more susceptible to errors. The NMC model does not predict that stress patterns in the lower part of the contrast scale are impossible—it does predict that such stress patterns should generally be less common than patterns in the upper part of the scale, and this prediction is clearly born out by the data.

Even allowing for occasional languages with stress patterns low on the harmony contrast scale, the number of languages which exhibit the “12...89” pattern of stress is rather conspicuous in (18). This stress region is also exceedingly narrow, as noted in §4.3.4. In short, the “12...89” pattern of stress is somewhat problematic for the specific instantiation of the NMC model under consideration, but not necessarily for the NMC approach in general. The harmony contrast score for this stress region depends in part on assumptions made in Chapter 2, just as the width of this stress region does. If the weight of heavy syllables were more than twice the weight of light syllables (whether universally or at least for those languages exhibiting the “12...89” stress pattern), then the “12...89” stress region would have a higher harmony contrast score. The harmony contrast score for this stress region also depends on the width of edge biases, i.e. on the parameter $g$ which determines how fast the effect of an edge bias drops off as a function of distance from the edge. Chapter 2 computed upper and lower bounds on $g$, and tentatively adopted a convenient $g$ value in the middle of the range of possible values. A smaller value of $g$ would produce a larger harmony contrast score for the “12...89” stress region. Interestingly, the “12...89” pattern of stress is often discussed alongside the “12...89/1” pattern of stress, which has a much higher harmony contrast score in (18). Although the
harmony contrast score for the “12..89” pattern of stress appears to be a little too low, the fact that the “12..89/1” pattern of stress has a much higher harmony contrast score accounts for the difference in relative frequency with which these two patterns are attested (cf. Odden, 1979, cited in Goldsmith, 1990:187).

Although most of the high contrast stress patterns are attested and most of the low contrast patterns are not attested, the number of languages exhibiting each stress pattern is not a monotonically increasing function of harmony contrast. There are at least three reasons why this is an expected result: (1) attested languages are at best a sample of possible languages; (2) languages are not independent; (3) harmony contrast is only one of the relevant factors limiting performance. I will elaborate these factors briefly, in turn.

The number of languages which have actually been instantiated and documented is uncontroversially taken to represent a small sampling of possible human languages. To the extent that attested languages represent a random sample of possible languages, random deviation is expected between the sample and the population of possible languages. The data on attested stress systems should reflect the gross distribution of possible stress systems across the harmony contrast scale, but is unlikely to accurately reflect the true distribution in every detail.

The problems inherent in trying to count languages have been discussed elsewhere, and I will comment on them only briefly here. Languages are not mutually independent, and this means any count of languages may be skewed by historical accident. Moreover, the decision to categorize related speech varieties as separate languages or as variants of a single language imposes a somewhat arbitrary dichotomy on a continuum of similarity. The accidental history of languages will distort the distribution of attested stress systems, and this distortion may be worsened by inconsistencies in categorizing languages versus dialects.

Finally, while harmony contrast is a plausible source of performance limitations on stress systems, it is not the only one. As I suggested above, the precision with which a parameter must be set is likely to limit stress systems, and so is the magnitude of parameter values required to produce a particular stress system. Stress systems with relatively small harmony contrast scores are more likely if they don’t require very large \( G \) or \( \theta \) values, and if the corresponding range of parameter values is not too small. Conversely, stress systems with relatively large harmony contrast scores are expected to be less common than other systems with comparable harmony contrast scores if they require large parameter values or if the corresponding parameter regions are very narrow. The “2” pattern of stress produced by the parameter region in the upper right part of (16) is expected to be relatively uncommon even though it has a large harmony contrast score in (18), because this stress region involves a large edge bias. The relative importance of the various limitations on stress patterns is an interesting question for further exploration.

There are a number of other conspicuous gaps in the upper part of (18), corresponding to stress patterns which are predicted by the NMC model, but which are unattested. The stress patterns “12..67/1”, “12..78/1”, “23..89/3”, “34..892/3”, and “34..89/3” have moderately high harmony contrast values, and cannot be ruled out on the basis of narrow parameter regions or large parameter values. For the reasons discussed above, the unattestedness of these stress patterns may very well represent sampling error. The NMC model predicts these patterns to be legitimate stress systems, and the existence of languages with such stress patterns would corroborate the NMC model of primary stress.

4.5. Summary

In the NMC model, a rich variety of stress patterns emerges from interactions between two continuously-valued parameters. The edge bias is a generalization of
extrametricality. In conjunction with the End Rule (i.e. a strong directional prejudice),
the strength of an edge bias at the beginning or end of a word determines whether a
language will exhibit quantity-sensitive or quantity-insensitive stress, and also determines
how far stress will be from the edge of a word. For the typology of stress patterns
defined by various amounts of edge bias interacting with a strong directional prejudice,
the one edge bias replaces a number of parameters and rules employed by metrical
accounts of these same patterns. Within a metrical account it is minimally necessary to
specify a foot type (e.g. left-headed vs. right-headed and bisyllabic vs. bimoraic; or
iambic vs. trochaic and syllabic vs. moraic). A metrical account must also specify what,
if anything, is extrametrical, and whether or not it’s necessary to erase foot structure after
it serves its purpose in the computation of primary stress.

The other parameter which plays a crucial role in generating the typology of stress
patterns considered in this chapter is directional prejudice. In the absence of an edge
bias, directional prejudice controls four fundamental stress patterns, “1L”, “12..89/1L”,
“12..89/1R”, and “1R”. In theories based on binary parameters, these four patterns
require at least two independent parameters. In Hayes (1995), for example, the parameter
End Rule (Right/Left) determines whether stress is assigned to the rightmost or leftmost
mark on the appropriate grid. The End Rule can apply either to the metrical grid, where
feet are constructed, or to the prominence grid. In typical bounded stress patterns like
“1L” or “1R”, the End Rule applies on the metrical grid. Unbounded stress patterns like
“12..89/1” are handled by a special rule projecting prominence distinctions onto a
prominence plane, so that the End Rule can pick out the edgemost heavy syllable. Hayes
doesn’t specifically parameterize this rule, but we might be able to reduce his analysis to
a binary parameter which determines whether the End Rule applies to the metrical grid or
to the prominence grid. The NMC theory unifies these two binary parameters (Right vs.
Left and Metrical Grid vs. Prominence Grid) into a single continuously-valued parameter,
Chapter 5: NMC in OT

The NMC theory of stress is based on constraints and constraint interactions. Since Optimality Theory (OT) likewise emphasizes constraints, it’s natural to ask what the relationship is between the two theories, and whether the constraints proposed for the NMC could just as well be translated into OT. In fact, the constraints of the NMC theory of stress are quite different from those of OT. This chapter will discuss differences between the OT and NMC approaches to constraints, then suggest that the NMC model of primary stress can be imported into OT as a self-contained submodule. Importing the NMC model into OT allows the constraints on primary stress to interact with other OT constraints. Interactions between primary stress and secondary stress are demonstrated in two languages, one in which the location of primary stress depends on secondary stress, and one in which the reverse relationship holds.

5.1. NMC and OT Approaches to Stress

The aspects of primary stress which must be accounted for are (at least) the five-fold principles of (1), repeated from Chapter 1.

(1) Culminativity—syllables compete for prominence
Directionality—the competition depends in part on the linear order of syllables
Syllable Weight—prominent syllables attract stress
Position—stress may be favored or disfavored near certain morphosyntactic edges
Lexical Stress—lexical entries may have explicitly stressed or unstressed vowels

In OT, a number of constraints have been proposed to account for the basic principles of stress. Syllable weight is accommodated via constraints preferring heavy syllables to be stressed rather than stressless (e.g. the WEIGHT-TO-STRESS principle of Prince & Smolensky, 1993), or favoring stress on heavier rather than lighter syllables (the PEAK-PROMINENCE constraint). Directionality and positional effects are both accounted for by aligning or disaligning a stressed syllable (or a metrical foot) with the left or right edge of a morphological constituent.

There is less agreement on how best to account for lexical stress in OT. In some cases lexical stress can be accounted for by placing metrical structure in underlying lexical representations. Underlying metrical structure is adequate to account for lexical stress patterns in monomorphemic words, or in some cases where a morpheme has a vowel which idiosyncratically attracts stress. However, underlying representations based on the privative metrical grid assumed in OT cannot accommodate idiosyncratically unstressed vowels in morphologically derived forms like those of Spanish and Polish discussed in Chapter 3. One alternative is to invoke special constraints for each lexical item, specifying the alignment or disalignment of stress relative to the edges of that item.1

A second alternative is to rerank constraints on a lexeme-by-lexeme basis.

Perhaps the biggest difference between OT and the NMC model is the treatment of constraint interactions. Constraints in OT are form a strict dominance hierarchy. The constraint ranking determines which constraints will be satisfied and which constraints will be violated when it’s not possible to fully satisfy them all. The strict dominance hierarchy severely limits constraint interactions—it’s not possible, for example, for two lower-ranked constraints to gang up and overpower a higher-ranked constraint.

1Interestingly, if phonological constraints can be specific to particular lexical items, it is possible to do away with underlying representations entirely. Each lexical entry can simply identify a set of constraints on the phonological realization of that lexical item. This approach to the lexicon is adopted explicitly in Declarative Phonology (e.g. [Bird, 1993 #142]; [Scobie, 1993 #164]), and has been discussed in relation to OT by Hammond ([1, 1995 #138]) and Inkelas ([1, 1994 #131]).
The NMC model takes a different view of constraints based on numerical interactions. In the NMC theory, the principles of (1) are embodied as pairwise competition for stress, directional prejudice, syllable weight, edge biases, and underlying prominence. Edge biases have a gradually diminishing effect at greater distances from the edge. Underlying prominence likewise is defined quantitatively. In the account of Spanish stress in §3.1, words like animal, carácter, and canibal lie along a continuum defined by the strength of their [UP]. Syllable weight combines with edge biases and underlying prominence, giving a single index of stress eligibility for each syllable. Eligibility is then used in conjunction with directional prejudice to determine the location of primary stress. Again, this involves quantitative interactions between syllables.

The case studies of Chapter 3 (Spanish, Latin, and Polish) cannot be mapped in any straightforward way from the NMC constraints to an OT account, because the NMC account of these stress systems relies on quantitative constraint interactions. It would be useful to have detailed accounts of these stress patterns within the OT framework, for comparison with the NMC accounts proposed in Chapter 3. Unfortunately, such accounts have not yet been proposed.\(^\text{2}\) To help fill this void, or at least illuminate it, I will sketch a straightforward OT approach to Spanish stress based on proposed universal constraints

\(^{\text{2}}\)The account of Latin stress in Prince & Smolensky ([1993 #32]) does not include enclitics, and I see no straightforward way to extend that account to cover the enclitic data. Hammond ([1995 #138]) discusses lexical stress in Spanish, but addresses only some of the facts discussed in chapter 3. Hammond doesn’t address stressless suffixes like the -ic in gránitico, consonant-final nouns like animal or canibal (and their plurals), verbs made from stems which condition antepenultimate stress in noun forms, like termina (V) vs. término (N), nor for effects of syllable weight on stress in nouns versus verbs.

employed by Prince & Smolensky (1993).\(^\text{3}\) This pure OT approach to Spanish runs into a constraint ranking paradox, and is unable to simultaneously account for the quantity-sensitivity of primary stress in Spanish and for basic patterns of lexical stress. Since the NMC model of primary stress facilitates a simple and comprehensive account of Spanish stress, I will propose importing the NMC model into OT as an encapsulated STRESS-HARMONY constraint. The STRESS-HARMONY constraint will be introduced and demonstrated following the discussion of a metrical OT approach to Spanish stress.

5.2. A Metrical OT Approach to Spanish Stress

In order to justify importing the NMC model into OT as a STRESS-HARMONY constraint, I will demonstrate that a straightforward alternative analysis in terms of standard OT constraints runs into a ranking paradox—there is no ordering of the relevant constraints which will account for the basic facts of primary stress in Spanish nouns.

The aspects of primary stress in Spanish which will be addressed here are listed in (2). These are a subset of the facts accounted for in the NMC analysis of Spanish in §3.1.

(2) a. Stress normally falls on the penultimate syllable, e.g. sabana(s).
   b. Stress normally falls on the final syllable of nouns without class markers, e.g. animal(es).
   c. Stress is retracted one syllable farther from the edge in lexically-marked forms, e.g. número(s), canibal(es).
   d. Stress retraction is generally prohibited if the last syllable of the noun stem is heavy, e.g. *cánasta.

The analysis will primarily involve the constraints BINARITY (feet contain two moras), WEIGHT (a heavy syllable is the head of its foot), N-STEM (primary stress is aligned with the end of a noun stem), NONFINAL (primary stress is not on the final

\(^{\text{3}}\)For exposition I adopt my own names for the constraints.
(3) saban-a-s

<table>
<thead>
<tr>
<th>Candidates</th>
<th>N-STEM</th>
<th>NONFINAL</th>
<th>BINARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. sa.ba.(nás)</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. as sa.(bá).nas</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. (sá.ba).nas</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(4) animal

<table>
<thead>
<tr>
<th>Candidates</th>
<th>N-STEM</th>
<th>NONFINAL</th>
<th>BINARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. as a.ni.(mál)</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. a.(ni).mal</td>
<td>*!</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. (á.ni).mal</td>
<td><em>!</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

By default, penultimate stress in words like sabánas ‘savannas’ means NONFINAL must dominate BINARITY. Otherwise stress would fall on the final syllable, producing *sab(ánas). N-STEM must also dominate BINARITY, or else stress would fall on the antepenultimate syllable, *(sába)nas. In order to place stress on the final syllable of words like animal, N-STEM must dominate NONFINAL. Otherwise stress would fall on the penultimate syllable, *animal. This produces the constraint ranking N-STEM >> NONFINAL >> BINARITY. These constraints are illustrated in (3) and (4).

In lexically-marked forms, like números and canibal, stress falls one syllable farther from the end of the word than in the default case. I analyze these forms as involving lexical entries with pre-specified (underlying) metrical feet. The constraint PARSE-FT requires output representations to respect underlying feet. PARSE-FT must dominate N-STEM, as in (5) and (6), or else the underlying foot would be ignored.

Now, the problem this analysis runs into is that primary stress in Spanish is quantity sensitive. As discussed in §3.1.5, antepenultimate stress is generally precluded in Spanish if the penultimate syllable of a word is heavy. If this quantity-sensitivity is to be accounted for in the grammar (following Harris 1995, and many others), then WEIGHT must dominate PARSE-FT, as shown in (7). Otherwise an underlying foot could freely generate forms like *cánasta, which violate the prohibition against antepenultimate stress in words with heavy penults.

But if WEIGHT dominates PARSE-FT, we encounter a problem in words like canibal. Tableau (6) is redone in (8), taking WEIGHT into account. As shown, the wrong output is selected, because the WEIGHT constraint disqualifies the target output (8d). One
option is to reconsider the underlying representation for caníbal. The representation employed in (6) and (8), \( \{ \ast \} \), has a bisyllabic foot grouping the stressed syllable caníbal with the following one (which would otherwise receive stress). For caníbal, it might suffice to employ a monosyllabic foot rather than a bisyllabic one, \( \{ \ast \} \). Given this underlying representation, candidate (8b) will be chosen rather than (8a), because (8b) will no longer violate \textsc{parse-fn}. This places stress on the appropriate syllable, caníbal. However, this will not account for stress in the plural form caníbales. A constraint tableau for this form is shown in (9). The tableau suppresses the undominated \textsc{weight} constraint, and considers only candidates which satisfy this high-ranking constraint.

Although it might be possible to employ a constraint against stress clash or some other constraint to rule out candidate (9b), there is reason to believe the underlying monosyllabic foot is not the appropriate way to represent this lexical stress pattern in Spanish (cf. §3.1.1 and §3.1.4). The monosyllabic foot representation marks a vowel as an idiosyncratic target location for stress, but the proper generalization for Spanish is that certain vowels idiosyncratically \textsc{avoid} stress. Thus, the derivational suffix \textit{-ie}, for example, conditions antepenultimate stress in words like granítico 'granitic' (cf. granito 'granite'). Similarly, in verb forms several inflectional suffixes condition antepenultimate stress, including the imperfect marker \textit{-ba} in forms like terminaba, terminábamos 'we finished', 'they finished', 'we finished'.

Given the quantity-sensitivity of primary stress in Spanish, it is difficult to find a set of OT constraints and constraint rankings which will account for basic lexical stress patterns. It's possible some other set of constraints might be more successful than the ones employed here, though I have tried several obvious alternatives only to arrive again at a ranking paradox. Alternatively, we might abandon the attempt to account for the deviance of nonce forms like *cánastu in the grammar of Spanish. If the deviance of
such forms reflects something other than grammaticality, then we can give a quantity-
sensitive account of Spanish stress, and avoid the ranking paradoxes of the quantity-
sensitive account. However, some extragrammatical mechanism must then be invoked to
account for the apparent quantity-sensitivity of Spanish stress, and the nature of this
mechanism remains unclear. A number of other aspects of Spanish stress also remain to
be accounted for, including the stress-shifting singular/plural forms like
régimen/régimenes.

The simplicity and comprehensiveness of the NMC account of Spanish stress in
§3.1 compares favorably with the abortive account outlined above which was based on
standard OT constraints. The advantages of the NMC account can be brought to OT by
using the NMC model of constraints on primary stress, encapsulated within a STRESS-
HARMONY constraint.

5.3. The STRESS-HARMONY Constraint

Although the NMC constraints are not readily translated into some functionally
equivalent set of constraints in OT, the NMC constraints on primary stress can be
 imported into OT wholesale. The NMC competition between syllables for stress
computes a pairwise harmony value for each syllable compared to every other syllable in
a word. In Chapter 4, I suggested that primary stress falls on whichever syllable beats all
the other syllables, as measured by pairwise harmony values. This assumption can be
implemented in a more general form as a constraint within OT:

STRESS-HARMONY—Syllable x is a better (primary) stress peak than syllable y if
the pairwise harmony values $M_{xj}$ are greater than $M_{yj}$ with j ranging over all
syllables in the word.

The advantage of incorporating the NMC margin of victory into an OT constraint
like STRESS-HARMONY is that the NMC model is (just) a theory of primary stress,
whereas OT is a general theory of phonology.4 The NMC model on its own yields a
straightforward account of a wide variety of primary stress systems, including Spanish,
Polish and Latin. If incorporated into OT, STRESS-HARMONY can interact with other
constraints, including the constraints on metrical feet which account for secondary stress.
If STRESS-HARMONY is ranked higher than constraints on foot construction, primary
stress assignment will appear to be autonomous with respect to secondary stress. If
STRESS-HARMONY is ranked lower than constraints on foot construction, stress will
appear to be assigned from the bottom up, with secondary stresses established first and
primary stress falling on one of the stressed syllables. These constraint interactions will
be illustrated in the following two sections on Wargamay and Polish.

5.4. Bottom-Up Stress in Wargamay

I will illustrate interactions between the STRESS-HARMONY constraint and
metrical constraints on stress within Optimality Theory by briefly discussing the stress
patterns of Wargamay, as described by Hayes (1995:140). The data from Wargamay are
of interest because the location of primary stress evidently depends on the secondary
stresses. Illustrative data is given in (10). Stresses in Wargamay fall on the first syllable
if it is heavy (long-voweled), and on even-numbered syllables counting from the end of
the word. However, the syllable following an initial heavy syllable is never stressed.
The first stressed vowel in a word receives primary stress. Long vowels (and hence,
heavy syllables) occur only in word-initial position.

4Actually, OT is not restricted to phonology, but is a general framework of
linguistic analysis based on violable constraints arranged in a rankable strict dominance
hierarchy. For present purposes it suffices that OT has broader coverage than NMC.
I will first consider words with five light syllables; stress in other words with only light syllables will follow directly from a proper treatment of the five-syllable case. Since stress in Wargamay is assigned in a bottom-up fashion, I begin by accounting for the distinction between stressed and unstressed syllables in terms of foot structure. This will involve standardmetrical constraints and an ordinary OT analysis. After accounting for the distinction between stressed and unstressed syllables, I will show how the NMC model can interact with foot structure to assign primary stress within the OT framework for the distinction between stressed and unstressed syllables. I will show how the NMC will interact with foot structure to assign primary stress within the OT framework via the STRESS-HARMONY constraint. Finally, I will extend the analysis to words with an initial heavy syllable.

Words with an odd or even number of syllables will be referred to as odd- versus even-parity words, respectively. Following Hayes, I analyze Wargamay stress in terms of bimoraic, left-headed feet constructed from the end of a word. The target parse of LLLLL is thus taken to be L(̃L L) (L̃ L), with the first syllable left unparsed (not incorporated into a foot). Momentarily setting aside the question of primary stress to focus on footing, the crucial parsing constraints are PARSE (syllables into feet), 4 ALIGN (feet with the end of a word), BINARITY (feet encompass two moras, i.e. one heavy syllable or two light syllables), and HEADLEFT (the first syllable of a foot is the head of the foot).

Since a single word may contain two feet, only one of which can actually be aligned with the end of a word, PARSE must dominate ALIGN. Also, since the initial syllable in odd-parity words is left unparsed, BINARITY must dominate PARSE. Otherwise all syllables would be gathered into feet, either by putting three syllables into a single foot, or by creating a degenerate foot with a single syllable. Anticipating the discussion of words with a heavy initial syllable, I also assume here that HEADLEFT dominates PARSE. This yields the partial constraint ranking (BINARITY, HEADLEFT) >> PARSE >> ALIGN. The interactions of these constraints are illustrated in (11).

Thus far we have an ordinary OT analysis of metrical structure. A standard metrical account would continue by invoking a constraint that puts primary stress on the leftmost foot head, say LEFTMOST, and this would work very nicely for Wargamay.

---

<table>
<thead>
<tr>
<th>Syllables</th>
<th>Stress Pattern</th>
<th>Example</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Initial Heavy</td>
<td>H L</td>
<td>múuba</td>
<td>'stone fish'</td>
</tr>
<tr>
<td></td>
<td>H LL</td>
<td>giibaRa</td>
<td>'fig tree'</td>
</tr>
<tr>
<td>b. 3 or 5 syllables</td>
<td>LL L</td>
<td>gagára</td>
<td>'dilly bag'</td>
</tr>
<tr>
<td></td>
<td>LL LL L</td>
<td>j uRágay-miri</td>
<td>'Niagara-Vale-from'</td>
</tr>
<tr>
<td>c. 2 or 4 syllables</td>
<td>L L</td>
<td>báda</td>
<td>'dog'</td>
</tr>
<tr>
<td></td>
<td>LL L L</td>
<td>gíj awúlu</td>
<td>'freshwater jewfish'</td>
</tr>
</tbody>
</table>

---

(footnote 4) I assume “unparsed” syllables are linked directly to the prosodic word.
However, metrical accounts of primary stress are ultimately inadequate crosslinguistically, as I’ve argued in previous chapters and in the discussion of Spanish above. Having argued that something like the NMC model is necessary to account for primary stress in some languages (like Spanish), I will now show that it is sufficient to also account for languages like Wargamay, within the context of OT. Thus STRESS-HARMONY replaces LEFTMOST or its equivalent in the analysis of Wargamay.

In order to obtain primary stress on the appropriate syllable, pairwise harmony values, $M_{ij}$, will be computed for each output candidate with primary stress on syllable $x$. Each pairwise harmony value measures how strongly the nonmetrical constraints favor primary stress on syllable $x$ over syllable $j$. If a candidate output has primary stress on syllable $x$, there will be one pairwise harmony value for every other syllable $j$ in the output candidate (excluding $j=i$). The pairwise harmony values for each candidate are sorted in ascending order to facilitate a worst-first comparison between candidates (higher pairwise harmony values are preferable to—more harmonic than—lower values).

In order to compute pairwise harmony it is necessary to determine appropriate values for the constraints of the NMC model. Primary stress in Wargamay falls as close to the beginning of the word as the foot structure will allow, suggesting a leftward directional prejudice. In fact, any leftward directional prejudice will do. The magnitude of the directional prejudice cannot be determined from the location of stress in Wargamay, because syllable weight distinctions occur only word-initially. Presumably factors like contrast maximization and parameter minimization would constrain the magnitude of directional prejudice actually employed by language users. However, I will not address these factors here since they are tangential to the interactions between pairwise harmony and other constraints on metrical structure. For concreteness, I will assume a moderate leftward directional prejudice value of $\theta = -\ln(2) = -0.69$; this favors stress on the left versus the right by a 2 to 1 margin.

There is no evidence of any edge bias effects in Wargamay, so I assume there are no active (nonzero) edge biases. The pairwise harmony values for a word of the form $LLLLL$ are laid out in (12). Each cell of the table shows the pairwise harmony, $M_{ij}$, associated with placing stress on syllable $x$ rather than syllable $j$.

The pairwise harmony values form the basis for evaluating candidates on the basis of STRESS-HARMONY, as illustrated in (13). Here, the constraints ranked higher than PARSE have been omitted for clarity. Each candidate output corresponds to one row of the pairwise harmony table (12), depending on which syllable of the candidate bears the primary stress. The pairwise harmony values from that row are sorted in ascending order for the STRESS-HARMONY constraint, and the resulting list of values is compared with the corresponding lists from the other candidate outputs. Candidates with lower values of STRESS-HARMONY are less optimal than candidates with higher values.

\[
\begin{array}{cccccccc}
\toprule 
 x & L & LLL & LLLL & LLLLL & LLLLL & LLLLL & LLLLL \\
\midrule 
 \hat{L} & 0.71 & 0.71 & 0.71 & 0.71 \\
 L & -0.71 & 0.71 & 0.71 & 0.71 \\
 \hat{L} & -0.71 & -0.71 & 0.71 & 0.71 \\
 L & -0.71 & -0.71 & -0.71 & 0.71 \\
 \hat{L} & -0.71 & -0.71 & -0.71 & -0.71 \\
\bottomrule 
\end{array}
\]
In candidates (13c) and (13d) stress falls on the initial syllable. Since the leftward directional prejudice favors stress on the initial syllable, the pairwise harmony values for this syllable versus the other syllables are all positive. However, in both of these candidates the first foot is separated from the end of the word by three syllables. These candidates therefore are worse violations of Align than are candidates (13a) and (13b) where the first foot is separated from the end of the word by only two syllables.

Candidates (13a) and (13b) have primary stress on the second and fourth syllables, respectively. In these candidates, the syllable with primary stress has negative pairwise harmony versus all the syllables farther to its left, again because the directional prejudice favors stress on the left. The STRESS-HARMONY constraint is evaluated by comparing the worst (smallest) pairwise harmony of each candidate first. Candidates (13a) and (13b) fair equally well (or poorly) on the basis of the first values in their STRESS-HARMONY lists. Proceeding to the next-worst values, however, candidate (13a) is preferred over (13b) because the second value in the STRESS-HARMONY list for (13a) is greater than the second value in the list for (13b).

<table>
<thead>
<tr>
<th>Candidates</th>
<th>PARSE</th>
<th>ALIGN</th>
<th>STRESS-HARMONY</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. [\text{L} (\hat{L}_L) (\hat{L}_L) ]</td>
<td>*</td>
<td>(\sigma)</td>
<td>-0.7, 0.7, 0.7, 0.7</td>
</tr>
<tr>
<td>b. [\text{L} (\hat{L}_L) (\hat{L}_L) ]</td>
<td>*</td>
<td>(\sigma)</td>
<td>-0.7, -0.7, -1.0, 0.7</td>
</tr>
<tr>
<td>c. [\hat{L}_L (\hat{L}_L) ]</td>
<td>*</td>
<td>(\sigma\sigma\sigma!)</td>
<td>0.7, 0.7, 0.7, 0.7</td>
</tr>
<tr>
<td>d. [\hat{L}_L (\hat{L}_L) ]</td>
<td>*</td>
<td>(\sigma\sigma\sigma!\sigma)</td>
<td>0.7, 0.7, 0.7, 0.7</td>
</tr>
</tbody>
</table>

On the basis of STRESS-HARMONY, candidates (13a) and (13b) are both worse than the candidates with initial stress in (13c) and (13d). ALIGN must dominate STRESS-HARMONY, or else primary stress would fall on the first syllable instead of the second syllable, as in (13c–d). This places STRESS-HARMONY at the bottom of the constraint ranking, where it serves only to determine which foot contains the primary stress. The STRESS-HARMONY values are based on the quantitative constraint interactions of the NMC model. However, these values do not interact with other OT constraints in a quantitative way. STRESS-HARMONY values determine a partial ordering of output candidates. The other OT constraints each specify their own partial ordering of output candidates, and the effect of STRESS-HARMONY in determining the optimal output depends on the position of STRESS-HARMONY within the strict dominance hierarchy of OT constraints.

Turning now to words that begin with a heavy syllable, these will be analyzed by parsing the initial heavy syllable, but leaving up to two light syllables after the heavy syllable unparsed in order to avoid stress clash. Thus, HLL₁ words will be parsed (\(\text{\hat{H}}\) \(\text{L}_L\) \(\text{L}_L\)) and HLL₂ words will be parsed (\(\text{\hat{H}}\) \(\text{L}_L\) \(\text{L}_L\)). This follows Hayes’ analysis. In addition to the constraints already introduced, the analysis of words with initial heavy syllables will involve the constraints PEAK-PROM (a heavier syllable is a better location for stress than a light syllable) and AVOID-CLASH (avoid stress on adjacent syllables). AVOID-CLASH must be ranked higher than PARSE, or else HLL₁ would be parsed into two feet as (\(\text{\hat{H}}\) \(\text{L}_L\) \(\text{L}_L\)). PEAK-PROM must also be ranked higher than PARSE, or else HLL₂ would be parsed as (\(\text{H}_L\) \(\text{L}_L\) \(\text{L}_L\)) in order to parse as many syllables as possible without creating a clash. This yields the overall partial constraint ranking (AVOID-CLASH, PEAK-PROM, BINARITY, HEADLEFT) >> PARSE >> ALIGN >> STRESS-HARMONY. Interactions of AVOID-CLASH and PEAK-PROM with PARSE and ALIGN are demonstrated on a word of the form HLL in (14). The proper parsing of HL words follows from the same constraints. STRESS-HARMONY does not play a pivotal role in HL and HLL words, because it is very low-ranked and simply picks out the leftmost stressed syllable as the bearer of primary stress.
The PEAK-PROM constraint is suspicious in the analysis of Wargamay, in that the
STRESS-HARMONY constraint also favors stress on a heavy syllable. The pairwise
harmony values for a word of the form HLL are laid out in (15). Each cell of the table
shows the pairwise harmony, $M_{i,j}$, associated with placing stress on syllable $i$ rather
than syllable $j$. The difference in STRESS-HARMONY for putting stress on the first syllable
versus the second syllable in a word of the form HLL is 2.12–(−2.12) = 4.24. This is
much greater than the difference in STRESS-HARMONY for putting stress on the first
syllable versus the second syllable in a word of only light syllables, 0.71–(−0.71) = −1.42.
However, OT imposes a strict dominance hierarchy on constraints, so the STRESS-
HARMONY constraint cannot overcome the force of ALIGN and PARSE, no matter how
much difference there is in STRESS-HARMONY between a heavy initial syllable and a
light one. Some other constraint (PEAK-PROM) is needed to ensure stress on an initial
heavy syllable. It’s interesting to note that the PEAK-PROM constraint might be entirely
superfluous here if, instead of strict dominance, STRESS-HARMONY interacted
numerically with constraints like ALIGN and PARSE. In any event, the STRESS-
HARMONY constraint encapsulating the NMC model is sufficient, in conjunction with
metrical constraints on secondary stress, to place primary stress on the appropriate
syllable in Wargamay.

5.5. Top-Down Stress in Polish

In Wargamay, STRESS-HARMONY is ranked below the constraints on foot
structure, and this results in a pattern of primary stress which depends on the location of
foot heads. That’s why the description of primary stress in words with all light syllables
in Wargamay must mention secondary stress. Polish illustrates a different situation, in
which primary stress does not depend on foot structure. The discussion below
demonstrates how the autonomy of primary stress relative to secondary stress in Polish
follows from ranking STRESS-HARMONY above ALIGN in the OT constraint hierarchy.

My description of interactions between primary and secondary stress in Polish
relies heavily on Rubach & Booij (1985). In Polish, the location of primary stress
depends only on principles of the NMC model, as described in Chapter 3. Primary stress
in Polish is most often on the penultimate syllable, but may occur on the antepenult or the
final syllable in cases of lexical stress. Secondary stress appears on odd-numbered
syllables counting from the beginning of the word, except that secondary stress never
appears on the syllable immediately preceding the primary stress. Polish secondary stress
is illustrated on variations of the word meaning ‘inhabitant of Constantinople’ in (16).
For simplicity, I will focus on seven-syllable word forms, \( \sigma\sigma\sigma\sigma\sigma\sigma\sigma \). The analysis I present of these forms generalizes to both shorter and longer Polish words. Secondary stresses are analyzed as involving left-headed bisyllabic feet, aligned as closely as possible with the beginning of a word. The target parse of \( \sigma\sigma\sigma\sigma\sigma\sigma\sigma \) is thus taken to be \( (\tilde{o}\sigma)(\tilde{o}\sigma)(\tilde{o}\sigma) \). I will begin by assuming some high-ranking constraint forces primary stress to fall on the penultimate syllable. After addressing interactions between primary and secondary stress, I will return to the issue of primary stress and suggest that the high-ranking constraint governing primary stress is none other than STRESS-HARMONY, embodying the NMC constraints on primary stress in Polish developed in Chapter 3.

The analysis will involve the constraints PARSE (syllables into feet), ALIGN (feet with the beginning of a word), BINARITY (feet encompass two syllables), and STRESS-HARMONY. HEAD-LEFT is also relevant, but in this analysis I assume HEAD-LEFT is undominated and omit it from the constraint tables. Finally, I assume that another high-ranking constraint (not specified here) forces content words to have a primary stress.

An alternate analysis of secondary stress within Polish words is possible which places the primary stress of odd-parity words into a right-headed foot, e.g. \( (\tilde{\circ}\sigma)(\sigma\sigma\sigma) \) rather than \( (\tilde{o}\sigma)(\sigma\sigma\sigma) \). In this alternative analysis HEAD-LEFT is dominated by ALIGN. However, I believe the analysis presented in the text is more consistent with patterns of secondary stress within Polish phrases. In any event, the present discussion of Polish is primarily concerned with the relationship between STRESS-HARMONY and ALIGN, and STRESS-HARMONY must dominate ALIGN regardless of where HEAD-LEFT is ranked.

Since a word may contain multiple feet, PARSE must dominate ALIGN. Otherwise a parse like \( (\tilde{o}\sigma)(\sigma\sigma\sigma)(\tilde{o}\sigma) \) would be preferred, with a single secondary stress at the beginning of a word (in addition to the fixed primary stress). BINARITY must also dominate ALIGN, or else a long string of syllables at the beginning of a word could be gathered into a single foot, producing parses like \( (\tilde{o}\sigma)(\sigma\sigma\sigma)(\tilde{o}\sigma)(\sigma\sigma\sigma) \). Moreover, BINARITY must dominate PARSE, or else we would expect either \( (\tilde{o}\sigma)(\tilde{o}\sigma)(\tilde{o}\sigma) \) or \( (\tilde{o}\sigma)(\tilde{o}\sigma)(\tilde{o}\sigma) \), with two adjacent stressed syllables. This produces the constraint ranking BINARITY \( > > \) PARSE \( > > \) ALIGN. This constraint ranking is demonstrated in (17).

All of the candidates considered in (17) have primary stress on the penultimate syllable, because I assumed a high-ranking constraint governs the location of primary stress in Polish. In order to obtain primary stress in the correct location, the parameters of the NMC model will be set to favor stress on the penultimate syllable, and pairwise harmony values will be computed for each candidate output. This requires a combination of rightward directional prejudice and a negative edge bias at the end of a word. Any directional prejudice greater than about 2 will suffice. For concreteness, I will assume a 15:1 ratio in favor of stress on the right, so the directional prejudice parameter will be \( \theta = \ln(15) \approx 2.7 \). With this directional prejudice, the edge bias which produces the greatest pairwise harmony contrast between the best and second-best candidates for
primary stress is about –2.1. Taking this as the appropriate edge bias allows us to compute pairwise harmony values. Key pairwise harmony values are given in (18).

The combination of directional prejudice and edge bias were chosen to favor stress on the penultimate syllable. This is reflected by the pairwise harmony values in the third row of the table in (18). The positive values in this row indicate that the penultimate syllable is favored over the other syllables, as discussed in Chapter 4. These pairwise harmony values form the basis for the `STRESS-HARMONY` constraint, which is illustrated in the constraint table in (19). As shown, `STRESS-HARMONY` must dominate `ALIGN`, or else primary stress in odd-parity words would fall on the antepenultimate syllable instead of the penult in order to put the rightmost foot as close to the beginning of the word as possible.

The analysis of Polish secondary stress is readily extended to include interactions with the various patterns of lexical primary stress discussed in §3.2, though I will not pursue that here. The crucial factor in Polish is that `STRESS-HARMONY` dominates the constraints on foot construction, so stress is assigned in a top-down fashion.

5.6. Summary

The advantages of the NMC model of primary stress can be incorporated into OT by encapsulating the NMC model within a `STRESS-HARMONY` constraint. This circumvents problems encountered in trying to account for Spanish stress using purely metrical constraints. Moreover, it allows the NMC model of primary stress to interact with other phonological constraints, including constraints on metrical feet and secondary stress. The ranking of `STRESS-HARMONY` relative to constraints on foot structure...
determines whether primary stress depends on feet or vice versa. In Wargamay, STRESS-HARMONY ranks below the relevant constraints on foot structure, so STRESS-HARMONY only determines which foot will have the primary stress. In Polish, STRESS-HARMONY outranks at least some constraints on foot structure, so the foot structure is forced to organize around the preferred location of primary stress.

The STRESS-HARMONY constraint allows the NMC model to be incorporated into Optimality Theory, where the combined nonmetrical constraints on primary stress can interact with other phonological constraints. The sufficiency of this approach depends not only on the adequacy of the NMC model itself, but also on the adequacy of the constraint interactions allowed by the strict dominance hierarchy of OT. If more complex interactions are required to give an account of interactions between primary stress and foot structure, etc., it may ultimately be necessary to employ quantitative constraint interactions in phonological processes outside, as well as inside, the NMC model.
We no longer perceive the country we have traversed,
and we think nothing of it; that which lies before us
becomes vaster and stretches still before us.

Jean-Jacques Rousseau

Chapter 6:

The NMC model is based on a few basic principles of primary stress, assumed to be universal across languages, combined with a small number of parameters of variation between languages. The principles and parameters of the NMC model account for the culminativity and directionality of primary stress, and also account for influence on the location of stress due to syllable weight, morphological structure, and the lexicon. The specific principles and parameters developed in the preceding chapters are summarized briefly below, with discussion of possible directions for future exploration. The chapter ends with a brief summary of advantages of the NMC model over metrical approaches to primary stress.

Constraints for and against stress on individual syllables are aggregated in a single stress eligibility score, \( E_i \), for each syllable \( i \). Stress eligibility takes into account the effects of syllable structure, morphological structure, and the lexicon:

\[
E_i = W_i + P_i + \sum G_i^j
\]

where

- \( W_i \) = syllable weight
- \( P_i \) = underlying (lexical) prominence
- \( G_i^j \) = bias from (morphological) edge \( g \)

The computation of stress eligibility depends on several parameters. Languages are free to choose which aspects of perceptual salience (syllable structure, sonority, tone, etc.) contribute to syllable weight, \( W_i \). In order to limit the scope of the initial analysis of the NMC model, I considered syllable weight to involve a simple binary distinction between light and heavy syllables. The assumption of binary syllable weight is an oversimplification in several respects. A number of languages exhibit more than two degrees of syllable weight (recall the five-way distinction of Pirahã, discussed in §1.3). Also, in different languages different aspects of syllable structure are relevant for stress (including sonority, tone, presence or absence of onset or coda, etc.). The NMC model follows metrical theory in simply stipulating syllable weight on a language-by-language basis. A more explanatory account of syllable weight would be a welcome addition to phonological theory.

It is also a property of individual languages that certain vowels of certain morphemes idiosyncratically attract or repel stress to some extent. Idiosyncratic stress in the NMC model is determined by underlying prominence, \( P_i \), specified in the lexicon along with other phonological features. Underlying prominence is an underlying phonological feature in that it directly reflects otherwise-unpredictable aspects of the surface phonological form. Like a traditional binary feature, [UP] indicates whether a particular vowel is idiosyncratically stressed (if the [UP] is positive) or unstressed (if the [UP] is negative). Unlike traditional phonological features, however, [UP] is not an element of a phonological representation to be acted upon or mapped onto a surface representation. Instead, [UP] is itself a constraint on the surface representation. Like all other constraints in the NMC model, [UP] is assigned a numeric weight which determines its strength relative to other constraints. The numeric weight allows different vowels in different lexical entries to exhibit various degrees of exceptionality with respect to other constraints on stress. The way that lexical stress is handled in the NMC model suggests a radical alternative to the standard conception of phonological features. In principle, all underlying phonological features might be replaced by lexical constraints on surface
representations (cf. Bird & Ellison, 1993 and Hammond, 1995 for two very different proposals in this general direction).

Finally, the relationship between stress and morphological structure is language-specific. The NMC model maintains that morphological effects on stress take the form of edge biases, attracting stress towards or repelling stress away from the edges of particular morphological constituents. If a language has morphological structures of the sort shown in (2), the language is free to specify whether the left and right edges of constituents X, Y, and Z individually attract or repel stress, and to what extent.

\[
(2) \quad \begin{array}{c}
\text{Y} \\
\text{X} \\
\text{Z}
\end{array}
\]

Edge biases project inward from the relevant edge, affecting the stress eligibility of all syllables within the constituent delimited by the edge. The effect of an edge bias is a gaussian function of distance from the edge, as specified in (3). In the present work, distance from an edge is measured in syllables, and all syllables are treated as having the same length. The usefulness of a distinction between short, monomoraic syllables and long, bimoraic syllables is well established in phonological theory, and it would be surprising if moras had no role to play in the assignment of primary stress. A natural way to accommodate moras within the NMC model would be to measure distance from an edge in moras rather than in syllables. Counting moras rather than symbols might even be seen as a move away from counting through a string of symbolic constituents, and a step towards measuring distance along the dimension of time.

\[
(3) \quad G_i = ||G|| e^{-(k-i)}
\]

where \( k - i = \text{distance from edge (measured in syllables)} \)
\( ||G|| = \text{strength of edge bias (effect on edgemost syllable)} \)

The culminativity of primary stress is accounted for in the NMC model by placing syllables in a winner-take-all competition for prominence. The competition depends in part on stress eligibility, but languages are free to specify how much the competition is skewed to favor syllables on the left over syllables on the right or vice versa. A minimum pairwise harmony value is calculated for each syllable, and the syllable with the greatest minimum pairwise harmony receives the primary stress. Other syllables do not receive primary stress (they may or may not receive secondary stress, but secondary stress generally depends on rhythmic principles outside the scope of the NMC).

Minimum pairwise harmony for syllable \( x \) is calculated as in (4).

\[
(4) \quad \min \left\{ M_{ij} \right\} = \begin{cases} E_i e^{-\theta/2} - E_j e^{\theta/2} & \text{for } j \text{ to the right of } x \\ E_j e^{\theta/2} - E_i e^{-\theta/2} & \text{for } j \text{ to the left of } x \end{cases}
\]

where \( \theta = \text{directional prejudice} \)
\( j \) ranges over all syllables other than \( x \)

The NMC model involves phonological, morphological, and lexical constraints on primary stress. Syllable weight imposes a phonological constraint on stress via the rich get richer principle favoring stress on syllables which are already perceptually prominent. Directional prejudice is also a phonological constraint favoring or disfavoring stress on syllables depending on their relative order within a string of syllables. Edge biases make stress sensitive to morphological structure by favoring or disfavoring stress near relevant constituent boundaries. Finally, underlying prominence reflects idiosyncratic, lexical stress behavior associated with particular morphemes. Knowing a language involves knowing the strength of each of these constraints on stress, i.e. knowing to what extent stress is associated with certain syllable structures, with the linear precedence of syllables within a word, with certain morphological edges, or with particular vowels of certain lexical items.
Examining primary stress from the viewpoint of speech reception rather than production, stress can be thought of as a cue for phonological or morphological structure, or for lexical identity. In languages where primary stress is highly correlated with syllable weight, the location of stress is a cue for some aspect of syllable structure. The directionality of stress combined with its culminativity makes stress at least a crude indicator of word boundaries. Edge biases establish relationships between stress and the edges of important morphological constituents; the flip side of this relationship is that the location of stress is a cue for the proximity of those edges. Finally, idiosyncratic placement of stress serves as a cue for the presence of the lexemes which condition idiosyncratic stress. The location of primary stress within a word can carry only a certain amount of information, so the stress cannot simultaneously signal all of the things above with 100% reliability. However, the location of primary stress can serve as a PROBABILISTIC cue for several aspects of linguistic structure simultaneously. The huge variety of stress patterns attested in human language suggests that languages are free to choose the degree to which stress is used as a cue for various aspects of linguistic structure.

The NMC model of primary stress represents an improvement over traditional metrical approaches to primary stress in several respects. By assigning primary stress directly, the NMC model accounts for top-down stress assignment without building abstract constituent structure which is often used merely as a temporary computation device in metrical theory. Also, in the NMC model, categorial behavior (stressing this syllable versus that one) emerges from continuously-valued constraints via a competition for prominence. By working from continuous rather than discrete parameters, the NMC model frees the language acquisition device from the need to make all-or-none parameter-setting decisions. Parameters can be adjusted incrementally, converging on appropriate values in a process of step-wise refinement.

By allowing multiple morphological domains to influence stress simultaneously (via edge biases), the NMC model accounts for interactions between morphology and stress without abstract intermediate representations or multiple levels of rule application. The quantitative and gradient nature of edge biases in the NMC accounts for a whole scale of extrametricality effects with a single continuous parameter. The gradience of edge biases in the NMC also accounts for the cross-linguistic three-syllable stress window, replacing a combination of metrical feet and extrametricality in accounting for this phenomenon in metrical theory.

Finally, by allowing the lexicon to quantitatively constrain phonological output representations, underlying prominence enables the NMC to account for lexical stress patterns without rule-invoking diacritics or duplicate grammars. Lexical stress is thus accounted for in the NMC model with phonological information in the lexicon, the same device used to account for other phonological characteristics of lexical items.
References


Appendix A

A.1. Gaussian Crossover Points

Let \( x_0^L \) and \( x_0^H \) be the distances from the edge where stress eligibility becomes positive for light and heavy syllables, respectively. For convenience, \( x_0^L \) and \( x_0^H \) will be set to 0 if the edge bias is not strong enough to render the edgemost syllable ineligible.

In general, the eligibility at distance \( x \) is given by

\[
E_x = W + G_x = W + |G| e^{-x^2/2}
\]

Solving for \( x_0^L \) and \( x_0^H \), the points at which the eligibility of light and heavy syllables, respectively, is zero:

\[
x_0^L = \begin{cases} 
1 + g \sqrt{2 \ln \left| \frac{|G|}{W^L} \right|} & \text{if } |G| \geq -W^L \\
0 & \text{otherwise}
\end{cases}
\]

\[
x_0^H = \begin{cases} 
1 + g \sqrt{2 \ln \left| \frac{|G|}{W^H} \right|} & \text{if } |G| \geq -W^H \\
0 & \text{otherwise}
\end{cases}
\]

Let \( oH \) and \( oL \) be the indexes of the edgemost eligible syllables in \( L \)words and \( H \)words, respectively. These indexes will be the smallest integers greater than \( x_0^L \) and \( x_0^H \):

\[
\sigma_L = \left\lfloor x_0^L + 1 \right\rfloor
\]

\[
\sigma_H = \left\lfloor x_0^H + 1 \right\rfloor
\]

In general, \( oH, oL \), \( x_0^L \) and \( x_0^H \) are bounded as specified by the following inequality:

\[
x_H \leq oH \leq oL \leq x_{L+1}
\]

Thus, if stress is assigned to the edgemost eligible vowel, \( x_H \) and \( x_{L+1} \) delimit a window within which stress will fall.

A.2. Penultimate Stress

Penultimate stress will be assigned by the End Rule if two conditions are satisfied: 1) the edge bias is strong enough to render a final heavy syllable ineligible, and 2) the edge bias is narrow enough so that the penultimate syllable is eligible even if light. The first condition requires that

\[ |G| \leq -W \]

The second condition requires that \( E_2 > 0 \), where

\[
E_2 = W^L + G_2 = W^L + |G| e^{-\frac{(2-1)W}{2}}
\]

Solving for \( g \) and taking advantage of the fact that \( |G| \leq -W \):

\[
g < \frac{1}{\sqrt{2 \ln 2}} \leq \frac{1}{\sqrt{2 \ln \left| \frac{|G|}{W^L} \right|}}
\]

If \( H \) is at most twice as big as \( L \), then

\[
g < \frac{1}{\sqrt{2 \ln 2}} = 0.849
\]
A.3. Antepenultimate Stress

Antepenultimate stress will be assigned by the End Rule if two conditions are satisfied: (1) the edge bias is strong enough and wide enough to render a penultimate heavy syllable ineligible, and (2) the edge bias is narrow enough so that the antepenultimate syllable is eligible even if light. The first condition requires that $E_3 < 0$, where

$$E_3 = W^n + G_1 = W^n + [\|G\|^2 W^n]^\frac{1-\gamma}{2\gamma}$$

The second condition requires that $E_1 > 0$, where

$$E_1 = W^k + G_1 = W^k + [\|G\|^2 W^k]^\frac{1-\gamma}{2\gamma}$$

We can solve the first condition for $\|G\|$ and substitute into the second condition to find an upper bound for $g$, but this upper bound is not as restrictive as the upper bound obtained for penultimate stress. The upper bound on $g$ for antepenultimate stress is:

$$g < \frac{\sqrt{3}}{\sqrt{2 \ln \left[ \frac{\|G\|^2 W^n}{W^k} \right]}}$$

More interesting is that value of $\|G\|$ required to produce antepenultimate stress rises rapidly as the edge bias becomes more narrow. If we assume that the strength of the edge bias needed to produce antepenultimate stress is no more $n$ times stronger than the weight of a heavy syllable, we can derive a lower limit on $g$. Solving the first condition for $g$,

$$g > \frac{1}{\sqrt{2 \ln \left[ \frac{\|G\|^2 W^n}{W^k} \right]}}$$

Some representative lower bounds for $g$ are given in the table below. Each row has a value for $\|G\|$ (in multiples of $H$), and the minimum value of $g$ which will allow antepenultimate stress to be achieved with an edge bias no stronger than the value given.
A.4. Potential Eligibility

If stress is assigned by selecting the edgemost eligible vowel, potential eligibility
(normalized to range from 0 to 1) is computed as:

\[ V_G = \frac{W_L - \min(E_{\alpha_L}, E_{\alpha_H})}{W_L} \]

Where the indexes of the stressed vowels in Lwords and Hwords, \( \alpha_L \) and \( \alpha_H \), are
computed as in (QQ-Gaussian Crossover Points), and the eligibility of these vowels is
computed in the usual way by adding their weight to the effect of the edge bias on them.

Appendix B

B.1. Equations for Lexical Stress in Spanish

To derive penultimate stress, the word edge bias must be strong enough to make the
stress eligibility of a final heavy syllable equal to zero. Assuming the weight of
heavy syllables is twice that of light syllables, and taking the weight of a light syllable
to be 1, the word edge bias must be at least as strong as \(-2\):

\[ E_s = H + G^{\text{Word(right)}} = 0 \]

\[ \|G^{\text{Word(right)}}\| = -H = -2 \]

To get final stress for nouns without gender markers like *animal*, the noun stem edge
bias must be strong enough to make the eligibility of a final heavy syllable greater
than zero. If the minimum stress eligibility which is distinct from zero is 0.25, the
nouns stem edge bias must be 0.25:

\[ E_s = H + \|G^{\text{Word(right)}}\| + \|G^{\text{Stem(right)}}\| = 0.25 \]

\[ \|G^{\text{Stem(right)}}\| = 0.25 - H - \|G^{\text{Word(right)}}\| = 0.25 - 2 = 0.25 \]

To get antepenultimate stress in words like *número* or *granítico*, the underlying
prominence associated with the penult must reduce the eligibility of the penult at least
to zero. This requires \( [-UP] = -0.51 \):

\[ E_{s-1} = L + P_{s-1} + \|G^{\text{Word(right)}}\|_{s-1} + \|G^{\text{Stem(right)}}\| = 0 \]

\[ P_{s-1} = -(1 - 0.74 + 0.25) = -.51 \]

To get shifting stress between *carácter* and *carácteres*, the underlying prominence of
the final stem vowel must be just strong enough to reduce the eligibility to zero in a
final heavy syllable with no gender marker (where the end of the stem is also the end
of the word). This requires \( [-UP] = -0.25 \):
The stem edge bias in verbs must be strong enough to raise the eligibility of a penultimate syllable to zero in spite of the underlying prominence it may have. This requires a verb stem edge bias of at least 0.31:

\[
E_{n+1} = H + P_{n+1} + \left[ G_{\text{Word}}^{\text{right}} \right] + \left[ G_{\text{VerbStem}}^{\text{right}} \right] = 0
\]

\[
P_{n+1} = -(2 - 2 + 0.25) = -0.25
\]

Verb inflectional morphemes are outside the verb stem, so they do not have to overcome the verb stem edge bias to reduce the eligibility of the penultimate syllable to 0. Antepenultimate stress in a noun like *cocinábamos* requires \([-\text{UP}]\) of \(-0.26\):

\[
E_{n+1} = L + P_{n+1} + \left[ G_{\text{Word}}^{\text{right}} \right] = 0
\]

\[
P_{n+1} = -(1 - 0.74) = -0.26
\]

To produce final stress as in *merció*, a verb inflection must have underlying prominence strong enough to raise the eligibility of a final light syllable above zero. This requires \([\text{UP}]\) of at least 0.25:

\[
E_{n+1} = L + P_{n+1} + \left[ G_{\text{Word}}^{\text{right}} \right] = 0.25
\]

\[
P_{n+1} = 0.25 - (1 - 2) = 1.25
\]

To produce antepenultimate stress in a verb inflection with a heavy penult, like *envidiemos*, the underlying prominence of the penult must reduce the eligibility of the penult to zero in spite of the weight of the syllable. Noting that the inflectional morpheme is outside the stem, this requires \([\text{UP}]\) of \(-1.26\):

\[
E_{n+1} = H + P_{n+1} + \left[ G_{\text{Word}}^{\text{right}} \right] = 0
\]

\[
P_{n+1} = -(2 - 0.74) = -1.26
\]

To produce antepenultimate stress in a noun with a heavy penult, like *Wáshington*, the underlying prominence of the penult must reduce the eligibility of the penult to zero in spite of the weight of that syllable. Noting that the edge of the stem is also the edge of the word, this requires \([\text{UP}]\) of \(-1.36\):

\[
E_{n+1} = H + P_{n+1} + \left[ G_{\text{Word}}^{\text{right}} \right] = 0
\]

\[
P_{n+1} = -(2 - 0.74 + 0.09) = -1.36
\]
B.2. Equations for Lexical Stress in Polish

To derive penultimate stress, the word edge bias must be strong enough to make the stress eligibility of a final heavy syllable equal to zero. Again, assuming the weight of heavy syllables is twice that of light syllables, and taking the weight of a light syllable to be 1, the word edge bias must be at least as strong as –2:

\[ E_s = H + G^\text{Word(right)} = 0 \]

\[ \|G^\text{Word(right)}\| = -H = -2 \]

To get antepenultimate stress when a P/A stem is followed by a single-syllable suffix, as in \( \text{gramatyk} \)-a, the last vowel of the stem must have a strong enough underlying prominence to reduce the eligibility of a penult at least to zero. This requires [UP] = –1.26:

\[ E_{s-1} = H + P_{s-1} + \|G^\text{Word(right)}\|^{-1} = 0 \]

\[ P_{s-1} = -(2 - 0.74) = -1.26 \]

To get antepenultimate stress in a bare A/P stem like \( \text{uniwersytet} \), the second-to-last vowel of the stem must have a strong enough underlying prominence to reduce the eligibility of the penult to at least zero. This requires a [UP] of –1.26, but associated with the second-to-last rather than the last vowel of the stem.

To get final stress in a bare F/P stem like \( \text{rezi\'i\'n} \), the last vowel of the stem must have a strong enough positive underlying prominence to raise the eligibility of the final syllable above zero. If the minimum stress eligibility which is distinct from zero is 0.25, words with a heavy final syllable require a [UP] of at least 0.25 (final stress in words with a light final syllable would require [UP] of at least 1.25, though I have no examples of such forms):

\[ E_{s-1} = H + P_{s-1} + \|G^\text{Word(right)}\| = 0.25 \]

\[ P_{s-1} = 0.25 - (2 - 2) = 0.25 \]

B.3. Equations for Latin Enclitic Stress

In order to render a two-syllable clitic stressless in a form like e\( \text{da-prop.ter} \), the negative bias at the right edge of the word must be strong enough to reduce the stress eligibility of a heavy penultimate syllable at least to zero. Again, assuming the weight of heavy syllables is twice that of light syllables, and taking the weight of a light syllable to be 1, the word edge bias must be at least as strong as –5.45:

\[ E_{s-1} = H + \|G^\text{Word(right)}\|^{-1} = 0 \]

\[ \|G^\text{Word(right)}\|^{-1} = -2 \times 2.72 = -5.45 \]

In order to place stress on the last syllable of the stem when followed by a one-syllable clitic in a form like s\( \text{ce.le.ri-que} \), their must be a positive bias at the right edge of the stem, strong enough to raise the eligibility of a light penult above zero. If the minimum stress eligibility which is distinct from zero is 0.25, the noun stem edge bias must be 1.25:

\[ E_{s-1} = L + \|G^\text{Word(right)}\|^{-1} + \|G^\text{Stem(right)}\|^{-1} = 0.25 \]

\[ \|G^\text{Stem(right)}\|^{-1} = 0.25 - (L + \|G^\text{Word(right)}\|^{-1}) = 0.25 - (1 - 2) = 1.25 \]

In a word with no clitic, like s\( \text{cl.e.ra} \), the edge of the stem is the same as the edge of the word, and the combined effect of the two edge biases must reduce the eligibility of a light penult at least to zero. This condition is satisfied by the edge bias values derived above, which result in stress eligibility of –0.54 on a light penult in a noncliticized word:

\[ E_{s-1} = L + \|G^\text{Word(right)}\|^{-1} + \|G^\text{Stem(right)}\|^{-1} = 1 - 2 + 0.46 = -0.54 \]
Finally, in a word with no clitic, like *a.mī.ča*, the combined effect of the two edge biases must leave the eligibility of the penultimate vowel above zero. If the minimum stress eligibility which is distinct from zero is 0.25, then the eligibility of a heavy penult in a noncliticized word must be at least 0.25. This condition is satisfied by the edge bias values derived above, which result in stress eligibility of 0.46 on a heavy penult in a noncliticized word:

\[
E_{w-2} = H + |G|e^{-4}
\]
\[
E_{w-1} = L + |G|e^{-1}
\]
\[
M_{w-2,w-1} = E_{w-2}e^7 - E_{w-1}e^7 < 0
\]
\[
H + |G|e^{-4} < (L + |G|e^{-1})e^0
\]
\[
H + |G|e^{-4} < e^0
\]

Although a light penult beats a heavy antepenultimate syllable, a light penult does not beat a heavy final syllable. This also places a lower bound on directional prejudice:

\[
E_w = H + |G|
\]
\[
E_{w-1} = L + |G|e^{-1}
\]
\[
M_{w-1,w} = E_w e^7 - E_{w-1}e^7 < 0
\]
\[
L + |G|e^{-1} < (H + |G|e^0)
\]
\[
L + |G|e^{-1} < e^0
\]

In order to produce the “21/2R” stress pattern of Awadhi, the directional prejudice must satisfy BOTH of the lower bound inequalities above. In addition, a light penult must beat a light final syllable, and this places an upper bound on the directional prejudice:
In order for a solution to exist which simultaneously satisfies the lower bounds as well as the upper bound, the lower bounds on directional prejudice must be less than the upper bound:

\[
\frac{H + \|G\|^{-1}}{L + \|G\|^{-1}} < \frac{L + \|G\|^{-1}}{L + \|G\|}
\]

The second inequality immediately above is trivially satisfied for all positive values of \( \|G\| \) because the denominator on the left is greater than that on the right (recall that \( H > L \), by definition), and the two numerators are the same. Solving the first inequality immediately above for \( \|G\| \) will give us a quadratic inequality. Assuming the weight of heavy syllables is twice that of light syllables, and taking the weight of a light syllable to be 1, \( \|G\| \) must satisfy:

\[
\left( e^{-2} - e^{-4} \right) \|G\| + \left( 2e^{-4} - e^{-2} - 2 \right) \|G\| - 1 > 0
\]

0.117\|G\| - 1.28\|G\| - 1 > 0

The roots of the quadratic inequality above are at \( \|G\| = 0.73 \) and \( \|G\| = 11.7 \). Any edge bias less than the first root or greater than the second will satisfy the inequality.

However, only a positive \( \|G\| \) will actually produce the desired stress pattern (see the stress region graphs in Chapter 4), so only the positive root is relevant. Any edge bias stronger than \( \|G\| = 11.7 \) will produce the “21/2R” stress pattern provided the directional prejudice falls between the lower and upper bounds specified above.

C.2. Stress Region Boundaries

Various strengths of edge bias at the beginning of a word can be combined with the directional prejudice continuum to define a two-dimensional parameter space. This parameter space is divided into various regions (henceforth “stress regions”) which produce different stress patterns. Most regions of the parameter space define stress patterns in which one syllable of a word beats all other syllables in pairwise competitions for stress. Other regions of the parameter space define stress patterns in which every syllable in some word loses to some other syllable in pairwise competition, e.g. syllable 1 beats 2, 2 beats 3, and 3 beats 1. The boundaries between these latter regions are harder to compute, and the analysis below is confined to the simpler cases in which one syllable of a word beats all other syllables.

The boundaries between stress regions are characterized by ties in the competition for stress. If syllable \( i \) beats \( j \) in a pairwise competition for stress, the pairwise harmony \( M_{ij} \) as defined in Chapter 4, is positive. If syllable \( i \) loses to \( j \), the pairwise harmony \( M_{ij} \) is negative. When there is a tie between \( i \) and \( j \), the pairwise harmony \( M_{ij} \) is zero.

When two syllables are equal competitors, the pairwise harmony of stressing one versus the other is zero:

\[
M_{ij} = E_i e^{\theta \tau} - E_j e^{\phi} = 0 \\
E_i = E_i e^{\theta}
\]

\[
W_i + \|G\| e^{-(\theta+\phi)} = \left(W_j + \|G\| e^{-(\phi+\theta)}\right)e^{\theta} = W_i e^{\theta} + \|G\| e^{-(\phi+\theta)}
\]

Solving for \( \|G\| \) as a function of directional prejudice,

\[
\|G\| = \frac{W_i - W_j e^{\phi}}{e^{\phi+\theta} - e^{\theta+\phi}} = \frac{W_i - W_j e^{\phi}}{e^{\phi+\theta} - e^{\theta+\phi}}
\]
If we interpret the $W$ terms in this equation as parameters which take on the values 1 or 2 for light or heavy syllables, then the equation defines a system of functions representing the boundaries between different stress regions. Assuming $L_2 = H$ and $W_r = L$, we get the function:

$$W = H, W_r = L.$$ 

This function specifies a lower bound on the relevant stress regions. Conversely, $W_r$ must be greater than the value specified by $W$ to fully delineate the target stress region. Therefore, it is useful to consider the values of $W$ and $W_r$ at which two different boundary curves intersect. The two curves are specified by $W$ and $W_r$ where the two curves take on the same value.

$$W - W_r = W - W_r.$$ 

The roots of this equation specify the values of $\epsilon$ at which the two boundaries intersect. As $W$ and $W_r$ refer to the first, second, and third syllables in a word, respectively, the quadratic equation will be convenient when $\epsilon$ is the syllable under consideration. In that case, each curve is a boundary between two different stress regions.

$$\epsilon = c = \frac{W_r - W}{W_r - W_r}, \quad \epsilon = \frac{W - W_r}{W_r - W_r}.$$ 

Rearranging terms yields a quadratic equation in $\epsilon$:

$$\left(\epsilon - \frac{W_r - W}{W_r - W_r}\right)^2 + \frac{W_r - W}{W_r - W_r} \epsilon = 0.$$ 

The roots of this equation specify the values of $\epsilon$ at which the two boundary curves intersect. It will be convenient to let $A$ and $C$ refer to the first, second, and third syllables, respectively. The quadratic equation degenerates to a linear equation with a single root, i.e., a single point of intersection between the two boundaries. This will happen when $\epsilon = c$, i.e., when the two boundaries coincide. In that case, the two boundaries coincide at $\epsilon = c$.

Because syllable 2 is to the right of syllable 1, placing stress on a right second syllable rather than a heavy initial syllable requires $W_r$ to be less than the value specified by $W$. The function $W_r = L, W = H$ above specifies an upper bound on the relevant boundaries between the relevant syllables.

To actually identify the parameter regions corresponding to a particular stress pattern, it is necessary to identify the boundaries which represent the upper and lower bounds of the appropriate stress region. The stress pattern in question places stress on the second syllable of a word beginning with $H$, for example, a heavy initial syllable must lose to a light second syllable, and a light second syllable must lose to a heavy third syllable. The syllables are determined from the general boundary equation:

$$\left(\epsilon - \frac{W_r - W}{W_r - W_r}\right)^2 + \frac{W_r - W}{W_r - W_r} \epsilon = 0.$$
If \( C = 0 \), there is a root at \( e^\theta = 0 \), which can be discarded since it involves an infinitely large negative directional prejudice ( \( \theta = \ln(e^\theta) = \ln(0) = -\infty \)). This will happen when \( i \neq k \), i.e. when the two boundaries under consideration both involve a certain syllable (syllable \( i \)) as the syllable on the LEFT in a pairwise comparison. In addition to the discarded root, the two boundaries intersect at:

\[
e^\theta = -\frac{B}{A} = -\frac{W_x e^{-(j-i)} - W_y e^{-(j+k)} + W_z e^{-(j-k)} - W_w e^{-(j+l)}}{W_x e^{-(j-i)} - W_y e^{-(j+k)}}
\]

Finally, if neither \( A = 0 \) nor \( C = 0 \), there are two roots, i.e. two points of intersection between the two boundaries (the case when \( B = 0 \) need not be considered since it represents a trivial case involving the intersection of a boundary with itself):

\[
e^\theta = -\frac{B \pm \sqrt{B^2 - 4AC}}{2A}
\]

C.3. 12..n/11. Stress Regions

The widest range of \( G \) values for the “12..n/11” family of stress patterns is obtained when the directional prejudice is very near 0. If directional prejudice is 0, stress simply falls on the syllable with the highest stress eligibility. In a “12..n/11” stress pattern, a light syllable at the edge must have higher eligibility than a heavy syllable at position \( n+1 \), just outside the stress window. This places a lower bound on \( G \):

\[
E_i > E_{x+1},
\]

\[
L + \|G\| > H + \|G\|e^{-\theta}
\]

\[
\|G\| < \frac{H - L}{1 - e^{-\theta}} = \frac{1}{1 - e^{-\theta}}
\]

At the same time, a heavy syllable at position \( n \), just inside the stress window, must have higher eligibility than a light syllable at the beginning of a word. This places an upper bound on \( G \):

\[
E_x > E_i,
\]

\[
H + \|G\|e^{-(j-i)} > L + \|G\|
\]

\[
\|G\| < \frac{H - L}{1 - e^{-(j-i)}} = \frac{1}{1 - e^{-(j-i)}}
\]

The table below shows the upper and lower limits for several values of \( n \), as well as the range of values between upper and lower limits (the upper limit minus the lower limit):

<table>
<thead>
<tr>
<th>( n )</th>
<th>Lower</th>
<th>Upper</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.0186574</td>
<td>1.5819767</td>
<td>0.5633193</td>
</tr>
<tr>
<td>3</td>
<td>1.0001234</td>
<td>1.0186574</td>
<td>0.0185339</td>
</tr>
<tr>
<td>4</td>
<td>1.0000001</td>
<td>1.0001234</td>
<td>0.0001233</td>
</tr>
<tr>
<td>5</td>
<td>1.0000000</td>
<td>1.0000001</td>
<td>0.0000001</td>
</tr>
</tbody>
</table>
Appendix D

These indexes of primary stress systems in D.1 and D.2 were compiled by a systematic search through Halle & Vergnaud (1987) and Hayes (1995), and by less systematic reference to other sources. Syllable Priority Codes (SPCs) are introduced in Chapter 1. The following notes may serve as a quick reference guide for interpreting the SPCs in appendices D.1 and D.2.

@w n  syllable weight level n; w1 is the lightest weight, w2 is heavier, etc.
@s  specifies a stressed syllable or foot head; @s is used when 1ry stress evidently depends on metrical feet, whether or not the requisite feet are realized phonetically as secondary stresses
“1@w3 / 23@s L”  
Stress syllable 1 if weight 3 (e.g. superheavy), else syl 2 if stressed else syl 3 if stressed; syllable numbers are determined relative to the (L)eft edge
“123/123/1R” = “123@w3 / 123@w2 / 1 R”  
If only syllable weight is involved (and secondary stress or metrical feet are not), the @ terms can be omitted.
“12L” = “12/2L”  
When last two syls mentioned would be the same (e.g. “12/2L”), the last one is often omitted.
“121R”=“12/1R”  
If only weight is involved and the context is clear, the “/” may be omitted.
“1 2 3 R” = “123R”  
Spaces are sometimes used to improve readability; they do not alter the meaning of an SPC.

D.1  Index of Attested Primary Stress Systems by Name

The notation used in SPCs is described in Chapter 1; also see the beginning of appendix D. For a number of stress systems in the index below, comments identify aspects of syllable structure relevant to syllable weight. The following conventions are employed:

VV = long vowel
V = short vowel if contrasted with VV, otherwise any vowel
v = reduced vowel
C = consonant
X = segment (vowel or consonant)
N = sonorant or nasal, as indicated
K = obstruent
δ = schwa
(X) = optional X, e.g. V(K) is a syllable with a short vowel optionally followed by an obstruent.
‘>’ = “is heavier than”, e.g. “VV > V” indicates syllables with long vowels are heavier than syllables with short vowels (whether opened or closed by a consonant); “VX > V” means that syllables with long vowels and closed syllables are heavier than short opened syllables.

Foot shapes are indicated, where relevant, using L and H to designate light and heavy syllables, and o to designate a syllable of arbitrary shape (where weight doesn’t matter). In some languages, primary stress is sensitive to more than two degrees of syllable weight. In those languages, unless indicated otherwise, L refers to the lightest syllable weight and H refers to all heavier weights.

1ry, 2ry = primary, secondary (stress)
<table>
<thead>
<tr>
<th>Language</th>
<th>SPC</th>
<th>Source(s), Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arabic, Bani-Hassan</td>
<td>1@w3/23@w2/2R</td>
<td>Halle &amp; Vergnaud, 1987:45; Interactions with feet may be relevant, e.g., 1@w3/2@w2/2R; 32s; cf. Palestinian Arabic; Feet(=)(\text{H}_i), (\text{L}_L) or (\text{H}), from left; (\text{VXC} &gt; \text{VX} &gt; \text{V})</td>
</tr>
<tr>
<td>Arabic, Classical</td>
<td>1/23.89/9R</td>
<td>Hayes, 1981:111/130, 1995:296; (\text{VXC} &gt; \text{VX} &gt; \text{V})</td>
</tr>
<tr>
<td>Arabic, Cyrenaican Bedouin</td>
<td>1@w3/23@s R</td>
<td>Hayes, 1995:226; Feet(=)(\text{L}_H), (\text{L}_L) or (\text{H}), from left; (\text{VXC} &gt; \text{VX} &gt; \text{V})</td>
</tr>
<tr>
<td>Arabic, Damascene</td>
<td>1@w3/23/3R</td>
<td>Halle &amp; Vergnaud, 1987:96; (\text{VXC} &gt; \text{VX} &gt; \text{V})</td>
</tr>
<tr>
<td>Arabic, Negev Bedouin</td>
<td>1@w3/23/2R</td>
<td>Hayes, 1995:226; Feet(=)(\text{L}_H), (\text{L}_L) or (\text{H}), from left; (\text{VXC} &gt; \text{VX} &gt; \text{V}); Lexical exceptions; (4\text{R} ) is optional in HLLH, HLLL</td>
</tr>
<tr>
<td>Arabic, Palestinian</td>
<td>1@w3/22@w2/2</td>
<td>Hayes, 1995:126; Feet(=)(\text{L}_L) or (\text{H}), from left; (\text{VXC} &gt; \text{VX} &gt; \text{V})</td>
</tr>
<tr>
<td>Aranda, Western</td>
<td>12L</td>
<td>Halle &amp; Vergnaud, 1987:48; (\text{CV} &gt; \text{V})</td>
</tr>
<tr>
<td>Araucanian</td>
<td>2L</td>
<td>Hayes, 1995:266, Hyman, 1977:41; (\text{1L} = 2\text{R} ) in bisyllables</td>
</tr>
<tr>
<td>Asheninca</td>
<td>234@w3/2</td>
<td>Hayes, 1995:288; Feet(=)(\text{L}_H), (\text{L}_L) or (\text{H}), from left; (\text{VV} &gt; {\text{IN}, \text{V(C)}} ) (&gt; {\text{N is a nasal consonant}}; \text{In feet}, \text{H}=\text{VV} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Language</th>
<th>SPC</th>
<th>Source(s), Comments</th>
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<tbody>
<tr>
<td>Au</td>
<td>12.89/1L</td>
<td>Hayes, 1995:297; Weight determined by vowel quality</td>
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<td>Awadhi</td>
<td>21/2R</td>
<td>Hayes, 1995:179; (\text{VX} &gt; \text{V})</td>
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<tr>
<td>Badimaya</td>
<td>1L</td>
<td>Hayes, 1995:198</td>
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<tr>
<td>Bergüner-Romansh</td>
<td>12R</td>
<td>Hayes, 1995:181; (\text{VX} &gt; \text{V})</td>
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<td>Bhojpuri</td>
<td>3R</td>
<td>Hyman, 1977:77</td>
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<td>Bidyara / Gungabula</td>
<td>1L</td>
<td>Hayes, 1995:199</td>
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<td>Cahuilla</td>
<td>1L</td>
<td>Hayes, 1995:133; Lexical exceptions are alluded to</td>
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<td>Cambodian</td>
<td>1R</td>
<td>Hayes, 1995:261</td>
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<tr>
<td>Cavinèña</td>
<td>2R</td>
<td>Hayes, 1995:202</td>
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<tr>
<td>Cayuga</td>
<td>23@s R</td>
<td>Hayes, 1995:223; Feet(=)(\text{L}_H), (\text{L}_L) or (\text{H}), from left; (\text{VV} &gt; \text{V})</td>
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<td>Cayuvava</td>
<td>3R</td>
<td>Hayes, 1995:205, 209; Lexical (1\text{R}, 2\text{R}; 2\text{y} ) stress on every 3rd syl in sequences of light syllables</td>
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<td>Chamorro</td>
<td>2R</td>
<td>Halle &amp; Vergnaud, 1987:204, Hayes, 1995:204; Lexical (1\text{R}, 3\text{R}; ) accented prefixes</td>
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<td>Cheremis, Eastern</td>
<td>12.89/9R</td>
<td>Hayes, 1995:296; (\text{V} &gt; \text{v} ) (full vs. reduced vowels); Optional (1\text{R})</td>
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<td>Cheremis, Meadow</td>
<td>1/23.89/1R</td>
<td>Hayes, 1981:132; ({\text{V} [+\text{tense}], \text{VC} } &gt; \text{V} {\text{[-tense]} } &gt; \text{v(C)})</td>
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<td>Cheremis, Mountain</td>
<td>23.89/2R</td>
<td>Hayes, 1981:123; (\text{V} &gt; \text{v} ) (full vs. reduced vowels); Lexical stress in words with no full vowels, so ambiguous with 23.89R; 12.89/1R in first member of compound</td>
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<td>Cheremis, Western</td>
<td>23.89/2R</td>
<td>Hayes, 1995:297; (\text{V} &gt; \text{v} ) (full vs. reduced vowels)</td>
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<td>Chuvash</td>
<td>12.89/9R</td>
<td>Hayes, 1995:296; (\text{V} &gt; \text{v} ) (full vs. reduced vowels)</td>
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<td>Czech</td>
<td>1L</td>
<td>Hayes, 1995:203, Hyman, 1977</td>
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<td>Dalabon</td>
<td>1L</td>
<td>Hayes, 1995:199</td>
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<td>Dehu</td>
<td>1L</td>
<td>Hayes, 1995:199</td>
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<tr>
<td>Diegueño</td>
<td>12R</td>
<td>Hayes, 1995:181</td>
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<tr>
<td></td>
<td></td>
<td>VX &gt; V (but C/C is light)</td>
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<td>Djingili</td>
<td>2R</td>
<td>Hayes, 1995:202</td>
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<td></td>
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<td>Lexical 1R, 3R</td>
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<td>Dyirbal</td>
<td>1L</td>
<td>Hyman, 1977</td>
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<td>English (adj. and verbs)</td>
<td>12R</td>
<td>Halle &amp; Vergnaud, 1987:230, VXC &gt; V(X); Lexical 3R</td>
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<td>English (nouns)</td>
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<td>Estonian</td>
<td>1L</td>
<td>Hayes, 1995:316</td>
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<td>Some lexical 1y and 2ry stresses;</td>
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<td>2ry stress at 3-syllable intervals in sequences of</td>
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<td>light syllables (optionally at two-syllable intervals)</td>
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<td>Fijian</td>
<td>12R</td>
<td>Hayes, 1995:142</td>
</tr>
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<td></td>
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<td>VV &gt; V</td>
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<td>Finnish</td>
<td>1L</td>
<td>Hayes, 1995:329</td>
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<td>2ry stress at 3-syllable intervals in sequences of</td>
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<td>French</td>
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<td>Halle &amp; Vergnaud, 1987:12, Stress domain is phrase</td>
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<td>Golin</td>
<td>12/89/1R</td>
<td>Hayes, 1995:278, High tone &gt; Low tone</td>
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<td>Greek, Ancient</td>
<td>12R</td>
<td>Hayes, 1995:181</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pitch accent interacts with tones</td>
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<tr>
<td>Gugu-Yalanji</td>
<td>1L</td>
<td>Hayes, 1995:204</td>
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<td>Gurkhali</td>
<td>12/1L</td>
<td>Hayes, 1995:93</td>
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<td>Hawaiian</td>
<td>12R</td>
<td>Hayes, 1995:181</td>
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<td>Weight depends in part on vowel height</td>
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<td>Hebrew,</td>
<td>12/21/1R</td>
<td>Hayes, 1995:73, V(V)V &gt; V</td>
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<td>Tiberian</td>
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<td>Feats(3R) or (H), from right; VXC &gt; VX &gt; V</td>
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<td>12/89/2/2@/82/2@</td>
<td>Hayes, 1995:164, VV &gt; V</td>
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<td>Kelkar</td>
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<tr>
<td>Hopi</td>
<td>12L</td>
<td>Hayes, 1995:261</td>
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<td></td>
<td></td>
<td>VX &gt; V</td>
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<tr>
<td>Hungarian</td>
<td>1L</td>
<td>Hayes, 1995:329</td>
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<td></td>
<td>2ry stress at 3-syllable intervals in sequences of light</td>
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<td>syllables (according to Szinnei)</td>
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<td>Icelandic</td>
<td>1L</td>
<td>Hayes, 1995:189</td>
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<td>Icúi Tupi:</td>
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<td>Hyman, 1977:77</td>
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<td>Indo-European</td>
<td>12/89/1L</td>
<td>Halle &amp; Vergnaud, 1987:72, Syl “weight” determined by</td>
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<tr>
<td>(proto-lg.)</td>
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<td>lexical accent</td>
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<td>Inga</td>
<td>12R</td>
<td>Hayes, 1995:181</td>
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<tr>
<td></td>
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<td>VN &gt; V(K), where N is sonorant</td>
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<tr>
<td>Javanese</td>
<td>21R</td>
<td>Hayes, 1995:262</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V &gt; ð</td>
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<tr>
<td>Karelian</td>
<td>1L</td>
<td>Hayes, 1995:329</td>
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<td></td>
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<td>2ry stress at 3-syllable intervals in sequences of light</td>
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<td>syllables (optionally at two-syllable intervals)</td>
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<td>Kawaiisu</td>
<td>12R</td>
<td>Hayes, 1995:181</td>
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<td>Kela</td>
<td>3R</td>
<td>Hayes, 1995:205</td>
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<tr>
<td></td>
<td></td>
<td>depends in part on vowel height</td>
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<td>Koya</td>
<td>1L</td>
<td>Idsardi, 1992:2</td>
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<td>Kwak’ala / Kwakiutl</td>
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<td>Hayes, 1995:297</td>
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<td>{VV, VN} &gt; V(K), where N is sonorant</td>
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<td>Lappish, Central Norwegian</td>
<td>1L</td>
<td>Hayes, 1995:199</td>
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<tr>
<td>Latin, Classical</td>
<td>23R</td>
<td>Mester, 1994</td>
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<td>VX &gt; V; Stem-final stress in cliticized forms</td>
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<td>Latvian</td>
<td>1L</td>
<td>Halle &amp; Vergnaud, 1987:12</td>
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<td>Lenakel</td>
<td>12R</td>
<td>Hayes, 1995:167</td>
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<td>{VV &gt; V (or tense &gt; lax)}; Lexical 1R, 3R</td>
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<td>Halle &amp; Vergnaud, 1987:190</td>
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<td>Hayes, 1995:278</td>
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<td>High tone &gt; Low tone</td>
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<td>Livonian</td>
<td>1L</td>
<td>Hayes, 1995:200</td>
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<td>Lushootseed</td>
<td>12.89/1L</td>
<td>Hayes, 1995:297</td>
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<tr>
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<td>V &gt; ḍ</td>
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<tr>
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<td></td>
<td>Lexical 1R, 2R</td>
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<tr>
<td>Mae</td>
<td>3R</td>
<td>Hayes, 1995:205</td>
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<td>Maidu</td>
<td>12L</td>
<td>Hayes, 1995:261</td>
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<td>VC &gt; V;</td>
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<td>Maithili</td>
<td>213/2 R</td>
<td>Hayes, 1995:149</td>
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<td></td>
<td>VV &gt; V</td>
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<td>Malakmalak</td>
<td>12@L</td>
<td>Hayes, 1995:203</td>
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<td>Feet=(go), from right; 3-syllable words 1L or 2L</td>
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<td>Malay</td>
<td>23R</td>
<td>Hayes, 1995:263</td>
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<td>V(X) &gt; ā; (per Lewis)</td>
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<td>Malay</td>
<td>21R</td>
<td>Hayes, 1995:263</td>
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<td></td>
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<td>V(X) &gt; ā; (per Winsteadt)</td>
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<tr>
<td>Malayalam</td>
<td>12/1L</td>
<td>Hayes, 1995:92</td>
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<td></td>
<td></td>
<td>VV &gt; V</td>
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<tr>
<td>Malecite / Passamaquoddy</td>
<td>23@R</td>
<td>Hayes, 1995:215</td>
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<td>Feet=(L₁H₁), (L₁L₁) or (H), from left; VV &gt; V</td>
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<tr>
<td>Language</td>
<td>SPC</td>
<td>Source(s), Comments</td>
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<td>Nyawaygi</td>
<td>251</td>
<td>Hayes, 1995:180; Feet=( LL) or (H), from right; VV &gt; V</td>
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<td>Odawa (Eastern)</td>
<td>3@sR</td>
<td>Hayes &amp; Vergnaud, 1987:183, Hayes, 1995:216; Feet=((HH), (LL) or (H), from left; VV &gt; V</td>
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<td>Ojibwa</td>
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<td>Hayes, 1995:200; Lexical 1R, 3R</td>
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<td>Ono</td>
<td>1L</td>
<td>Hayes, 1995:261; VV &gt; V; Stress domain is phrase</td>
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<td>Onondaga</td>
<td>2R</td>
<td>Hayes, 1995:178; Lexical 4R</td>
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<td>Ossetic</td>
<td>12L</td>
<td>Hayes, 1995:266; Lexical 1R, 3R</td>
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<td>Paiute, Southern</td>
<td>2L</td>
<td>Hayes, 1995:266</td>
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<td>Parnkalla</td>
<td>3R</td>
<td>Hayes, 1995:205</td>
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<td>Pintupi</td>
<td>1L</td>
<td>Hayes, 1995:62</td>
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<td>KVV &gt; GVV &gt; VV &gt; KV &gt; GV (K=-voice), G=[+voice])</td>
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<td>Piro</td>
<td>2R</td>
<td>Hayes, 1995:201</td>
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<td>Pitta-Pitta</td>
<td>1L</td>
<td>Hayes, 1995:201</td>
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<td>Polish</td>
<td>2R</td>
<td>Hayes &amp; Vergnaud, 1987:57, Idsardi, 1992; Lexical 1R, 3R</td>
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<td>Rotumen</td>
<td>12L</td>
<td>Hayes, 1995:trochaic</td>
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<td>12.89/1L</td>
<td>Idsardi, 1992:51; Lexical accent</td>
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<td>Sanskrit, Vedic</td>
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<td>Selkup</td>
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<td>Hayes, 1995:201</td>
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<td>Seminole / Creek</td>
<td>12@sR</td>
<td>Halle &amp; Vergnaud, 1987:59, Hayes, 1995:64; Feet=(LH), (LL) or (H), from left; VX &gt; V; Stress is realized as a high tone</td>
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<tr>
<td>Seneca</td>
<td>252</td>
<td>Halle &amp; Vergnaud, 1987:100, Hayes, 1995:225; {VC; VCV}&gt;V; Feet=(LL), from left; Rightmost nonfinal even syl attracts stress if closed or followed by closed syl; no stress if no closed syl</td>
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<td>Sentani</td>
<td>12R</td>
<td>Hayes, 1995:331; VC &gt; V (VV does not occur); 2ry stress at 3-syl intervals in sequences of light syls</td>
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<td>Serbo-Croatian</td>
<td>12.89/1L</td>
<td>Hayes, 1995:278; High tone &gt; Low tone; Ambiguous with 12.89L, since all words have a high tone</td>
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<td>Shoshone,</td>
<td>21L</td>
<td>Hayes, 1995:180; Optionally 1L</td>
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<td>Tümpisa</td>
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<td>Harris, 1995; Lexical 1R, 3R</td>
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<td>Spanish</td>
<td>2R</td>
<td>Hayes, 1995:204; Lexical 3R</td>
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<td>Swahili</td>
<td>2R</td>
<td>Hayes, 1995:177; Hyman, 1977:42; 1R, 3R in some verbs</td>
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<td>Tagalog</td>
<td>2R</td>
<td>Hayes, 1995:180</td>
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<td>Tanna,</td>
<td>2R</td>
<td>Hayes, 1995:180</td>
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<td>Southwest</td>
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<td>Tibetan, Lhasa</td>
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<td>Hayes, 1995:297; VV &gt; V</td>
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<td>Tol</td>
<td>12R</td>
<td>Hayes, 1995:181; VX &gt; CV</td>
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<td>Tongan</td>
<td>12R</td>
<td>Hayes, 1995:181; VX &gt; CV (VC does not occur)</td>
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<td>Tübataulabal</td>
<td>1R</td>
<td>Hayes, 1995:264</td>
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<td>Turkish</td>
<td>1R</td>
<td>Halle &amp; Vergnaud, 1987:53, Inkelas, 1994; Lexical 2R, 3R stems; Prestressing suffixes</td>
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<td>Turkish</td>
<td>23/2R</td>
<td>Inkelas, 1994; Place names and some loans only; VX &gt; V; Lexical 2R</td>
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<td>Ulwa</td>
<td>12L</td>
<td>Hayes, 1995:trochaic</td>
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<td>Language</td>
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</tr>
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</tbody>
</table>
| Unami      | 23@ RS | Hayes, 1995:211  
|            |     | Feet=(L\,H), (L\_L) or (H), from left; VX > V |
| Votic      | 1L  | Hayes, 1995:201                             |
| Wangkumara | 1L  | Hayes, 1995:202                             |
|            |     | Lexical 1R, 3R                             |
| Wargamay   | 12@ L | Hayes, 1995:140  
|            |     | Feet=(L\_L) or (H), from right; VX > V |
| Yana       | 12\_89/1L | Hayes, 1995:297  
|            |     | VX > V                                     |
| Yapese     | 12/1R | Hayes, 1981:108  
|            |     | VX > V                                     |
| Yawelmani  | 2R  | Hayes, 1995:204                             
|            |     | Lexical 3R                                 |
| Yil        | 12/IL | Hayes, 1995:93                             |
| Zoque,     | 2R  | Hayes, 1995:104                             |
| Chimalapa  |     |                                          |

### D.2. Index of Attested Primary Stress Systems by SPC

The tables below identify stress systems by SPC. See beginning of Appendix D for a description of SPCs and sources.

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<th>SPC (Long Length)</th>
<th>SPC (Short Length)</th>
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<td>12L (3+)</td>
<td>1L (2+)</td>
<td>Aranda, Western</td>
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<td>12L</td>
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<td>Hopi</td>
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<td>Maidu</td>
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<td>Rotumen</td>
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An accurate description of primary stress in many languages must distinguish between the stress pattern of words above a certain length and the stress pattern of words below that length. In the following table, the first column identifies the stress pattern observed in words of sufficient length. Where available, the minimum length is specified in parentheses; “12L (3+)”, for example, indicates a stress system which assigns “12L” stress to words of 3 or more syllables. The second column (where the relevant information was available) identifies the stress pattern assigned to shorter words.
<table>
<thead>
<tr>
<th>SPC (Long Length)</th>
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