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Phonological weight

Abstract

Grammars frequently categorize syllables for prosodic purposes, treating one class as heavier (e.g. more stress-attracting) than another. While such categorization is usually dichotomous, complex and gradient scales are also attested, with various organizational criteria. This article reviews the range of phenomena that invoke weight distinctions and introduces some current debates concerning weight, touching on topics such as the syllable versus interval as the domain of weight, rich scalarity, process and position specificities, the role of onsets, the phonetic basis of categorization, and the mora.

In order to capture generalizations about the phonological forms of words and phrases, it is often necessary to divide syllables into classes, such that one class patterns as prosodically "heavier" than another. For example, in many languages, the location of stress in words is determined by weight, such that stress skips over one or more light syllables in order to land on a heavy one. Heavy syllables are typically longer or more prominent than their light counterparts. Numerous schemes for categorization are attested; for instance, a language might treat any syllable containing a long vowel as heavy, and all other syllables as light (Section 1.1). While such divisions are most often binary, scales of weight can be more complex, comprising three or more levels, or perhaps even dissolving into such a fine grain of detail that the phenomenon diagnoses a gradient continuum of weight (Section 2.3).

The present article has two parts. The first surveys phonological phenomena claimed to invoke weight, including some that are often overlooked in such discussions, such as allomorphy (Section 1.6) and end-weight (Section 1.7). The second turns to current issues in the analysis of weight-based phenomena, such as whether the syllable or interval is the domain of weight, whether onsets can bear weight, highly complex or gradient scales, process specificity, positional specificity, the phonetic underpinnings of scalarity, and finally the status of the mora as a unit of weight. Given space constraints, emphasis is on outlining the issues and their empirical foundations rather than on enumerating proposals for specific constraints.

1 Weight-sensitive phenomena

Phonological weight is claimed to play a role in several grammatical systems, including stress, meter, prosodic minimality, tone licensing, compensatory lengthening, syllable structure constraints, allomorphy, reduplication, and constituent order. These phenomena are introduced in this first part before turning to analytical issues in Section 2.

1.1 Stress

Stress placement in words is often sensitive to syllable weight. Latin stress, for instance, distinguishes between light and heavy syllables. Any syllable ending with a short vowel is light; all others are heavy. In words of three or more syllables, stress falls on the penult (second-to-last syllable) if it is heavy (e.g. *prae.féc.tīs*, *op.tā́.tīs*), otherwise the antepenult (e.g. *dí.gi.tīs*). Roughly a third of the world's stress systems are weight-sensitive (39% of 500 relevant languages in WALS, Goedemans and van der Hulst 2013; 30% of 742 in StressTyp2, Goedemans et al. 2015; 44% of 310 in Gordon 2006). These databases/surveys can be consulted (online in the first two cases) for more details concerning the typology of weight distinctions for stress, which are only briefly reviewed here (see also Gordon 2002).

The vast majority of weight-sensitive stress systems (87% in Gordon 2006) are described as treating weight as binary.[1] Two roughly equally frequent CRITERIA (i.e. schemes for categorizing syllables as heavy or light) stand out as being far more common than all others. The first is the "Latin criterion" mentioned above, by which all and only short-vowel-final syllables are light. The other (as in, e.g., Khalkha Mongolian) treats a syllable as heavy iff it contains a long vowel (usually including diphthongs). These criteria differ from each other only in their treatment of syllables with a short vowel plus coda (i.e. the rime V̆C),[2] which is heavy for Latin but light for Khalkha. Crucially, however, VV is heavy in both cases. There is perhaps no language that treats V̆C as heavier than VV for stress.

Beyond the Latin- and Khalkha-type criteria, several other less frequent schemes are attested. A number of languages categorize syllables based on vowel centrality, height, or (underlying) reducedness (e.g. de Lacy 2004, Gordon 2006, Nevins and Plaster 2008; cf. de Lacy 2014).[3] In such cases, the heavier (i.e. more stress-attracting) vowels are usually more open or peripheral, suggesting that their weight may correlate with greater duration (see, however, de Lacy 2007: 294 for counter-evidence). More generally, greater weight correlates with (if anything) greater sonority. This holds of the vowel criteria just mentioned, of the asymmetry between V̆C and VV discussed above (namely, that only V̆C can be light), and of certain stress systems that treat sonorant codas as heavier than obstruent ones (Zec 1988, 1995, 2003, Gordon 2006). Additionally, laryngeals and geminates sometimes receive special treatment in stress criteria. In some languages, syllables closed by glottal stops, but not other consonants, are heavy, or vice versa (Crosswhite 2006, Gordon 2006: 131). In others, syllables closed by geminates, but not other codas, are heavy (see Section 1.6 for an example).

[1]This figure likely underestimates the incidence of more complex scales, since (a) systems traditionally described as binary sometimes turn out to exhibit more complex sensitivity in some contexts (e.g. English in Section 2.3) and (b) systems described as being "lexical," "diacritic," or "free" (within morphemes) sometimes turn out to exhibit significant weight-based tendencies (e.g. Russian in Section 2.3).

[2]The rime (or rhyme) is the portion of the syllable excluding any pre-vocalic (i.e. onset) consonants, which are usually irrelevant for weight (Section 2.2). C represents a consonant, C_0 a sequence of zero or more consonants, V̆ a short vowel, VV a long vowel or (heavy) diphthong, V any vowel, and $<$ "is lighter than."

[3]Some phonologists do not regard sonority-driven stress as reflecting "weight" per se (see Section 2.5).

Ternary or more complex scales are also possible. The most common ternary scale is $\breve{V}$ < $\breve{V}$C < VV, as in, e.g., Kashmiri (Morén 2000). See Section 2.2, Section 2.3, and Section 2.5 for further discussion. While categorical criteria rarely invoke onsets, several alleged cases of onset-driven weight have been put forth (Section 2.2). Interestingly, for onset-driven criteria, the sonority generalization mentioned in the previous paragraph is reversed: Sonorant onsets are evidently treated as (if anything) lighter than obstruent ones (Section 2.2; Gordon 2005).

1.2 Meter

In many poetic traditions, meters regulate the distribution of heavy and light syllables within the line. Vedic Sanskrit, for instance, exhibits a set of meters collectively known as "dimeter" in which each line is eight syllables long. The fifth and seventh positions are normally (with exceptions) light, the sixth heavy, and the remaining positions less strictly regulated (Oldenberg 1888, Arnold 1905). Sanskrit meter observes the Latin criterion in Section 1.1, whereby $\breve{V}$C is heavy. Indeed, this same criterion is found in all of the 17 languages with quantitative (i.e. weight-sensitive) meters surveyed by Gordon (2006: 207).

Additionally, Persian verse exhibits a ternary distinction, such that superheavy syllables are metrified as if they were heavy-plus-light sequences (Hayes 1979b). The Khalkha criterion (long vowel $\Leftrightarrow$ heavy) is rarer for metrics than for stress, but may be attested in Kayardild (Evans 1995) and Avestan (Kümmel 2016). Ryan (2011a) argues that quantitative meters, while usually described as binary, sometimes evince evidence of sensitivity to highly complex scales of weight. For example, while Homeric Greek is said to observe the Latin criterion, statistical analysis corroborates an ancient idea that certain heavy positions ("bicipitia") are more tolerant of heavier (e.g. long-voweled) heavies than others ("longa"). By comparing the ratios of different types of heavy syllables in bicipitia vs. longa (and controlling for various confounds), Ryan demonstrates that poets consider finely articulated scales of weight in choosing how to align syllables with metrical positions.

1.3 Prosodic minimality

Prosodic minimality refers to the minimum size requirements that a language imposes on phonological words (as opposed to grammatical words, such as certain clitics, e.g. English *'s*). For example, in many languages, including Latin, a monosyllabic word with the rime $\breve{V}$ is illegal, while $\breve{V}$C, VV, and larger rimes are legal. In Latin, this minimum is evident both from the static distribution of roots (almost none being $\#C_0\breve{V}\#$) and in alternations that repair an otherwise subminimal input. For example, /dă/ "give," as inferred from suffixed forms such as [dă-re] "to give," is lengthened to [daː] when unsuffixed (Mester 1994).

Thus, Latin exhibits the same criterion for weight in the context of prosodic minimality that it observes for stress (Section 1.1). Analysts such as McCarthy and Prince (1986) have capitalized on this parallelism, noting that since a monosyllable must be stressed, it must comprise a foot, and independent facts require that feet in Latin be bimoraic. Thus, it is no coincidence that Latin has the same criterion for both stress and minimality. Many languages, however, do not exhibit such parallelism (Garrett 1999, Gordon 1999).

1.4 Tone licensing

Tone licensing is often treated as being weight-driven (e.g. Hyman 1985, Zec 1988), most frequently in the suggestion that (certain) contour tones are confined to heavy (or bimoraic) syllables. In Thai, for instance, the full range of five tonal contrasts (viz. high, low, mid, rising, and falling) is available only on a syllable with a long vowel or a short vowel plus sonorant coda. V̆ and V̆T rimes (where T represents an obstruent) support only two tones (high and low; Gandour 1979). Gordon (1999 et seq.) finds that this Thai criterion is the most widespread for tone licensing, despite being rare for stress (Section 2.4); see also Zhang (2004).

1.5 Compensatory lengthening and syllable structure

Compensatory alternations, such as lengthening a vowel to compensate for a deleted coda (e.g. historical **esmi* yielding [eːmi] in Attic Greek), are often considered to reflect weight in the sense that they preserve the number of weight units (e.g. moras) in the rime (Hayes 1989). As such, onset loss is less likely to trigger compensatory lengthening, though see Topintzi (2010) for possible cases of vowel lengthening caused by onset deletion. Similarly, languages often impose constraints on syllable form that reflect weight, such as shortening long vowels in syllables with codas to avoid exceeding two units of weight in the rime.

1.6 Allomorphy and reduplication

Allomorphy can be sensitive to syllable weight in the sense that an affix can have different surface realizations depending on the weight profile of its base. In many such cases, the allomorphy can be analyzed as following from more general principles of metrical structure or phonotactics. For example, consider the genitive plural of vowel-final bases in Estonian (Mürk 1991, Kager 1996). In a word with no superheavy syllables, the suffix is *-te* when the base has an even number of syllables (e.g. 1a–b), and otherwise *-tte* (1c). If the word begins with a superheavy syllable, the generalization is inverted: *-tte* is employed for an even parity base (1d), otherwise *-te* (1e). Kager (1996) analyzes this selection in terms of foot structure, as the parenthesized feet in (1) suggest: The suffix is geminated iff doing so would close a stressed syllable, making it heavy.

(1)
a. (vísa)-te ‘tough-GEN.PL’
b. (téle)(fòni)-te ‘telephone-GEN.PL’
c. (pára)(jà-tte) ‘suitable-GEN.PL’
d. (áasː)(tà-tte) ‘year-GEN.PL’
e. (áatː)(riùmi)-te ‘atrium-GEN.PL’

In other cases, however, it is less obvious that weight-sensitive allomorphy reduces to foot structure. Consider, for instance, the Finnish nominalizing suffix *-ntV*, which has a high allomorph *-nti* and a low allomorph *-nta* ∼ *-ntä* (Anttila 2006).[4] Anttila finds that by far the strongest predictor of the choice between the high and low allomorph is the weight of the final syllable of the base, not stress or foot structure.

Affix location can arguably also be sensitive to syllable weight. Sande (2014) provides a case from Amharic. In Amharic, a syllable is heavy iff it is closed by a geminate (188). Pluralization of adjectives and iterativization of verbs is marked by an infixing CV reduplicant, but only if the base contains a geminate. If so, the reduplicant immediately precedes the geminate.[5] If the base contains no geminate, an alternative construction must be employed, namely, the suffix *-otʃtʃ* in the case of adjectives and periphrasis in the case of verbs. Sande claims that this pattern cannot be analyzed as attraction of the infix to a stressed syllable. For one, all bases have stress, but only bases with heavies permit reduplication.

More familiarly in reduplicative systems, weight is often invoked in some form as a restriction on the shape of the reduplicant itself (cf. McCarthy and Prince 1986, 1990, 1995). For example, in Mokilese (Blevins 1996), the reduplicant prefix for the progressive aspect (underlined) must be a heavy syllable (C_0VC or C_0VV), as in (2). This prosodic condition is enforced on the surface: In (2c), two consonants are copied after the vowel because one resyllabifies as an onset to the following syllable and is therefore weightless. If no cluster is available to copy in such cases, a consonant or vowel must be lengthened, as in (2d–e).

(2)
- a. pɔd-.pɔ.dok ‘planting’
- b. sɔː-.sɔː.rɔk ‘tearing’
- c. an.d-an.dip ‘spitting’
- d. al.l-a.lu ‘walking’
- e. paː-.pa ‘weaving’

Beyond being a target for the shape of the affix, sensitivity to weight can play out in more complex ways in reduplication, which are generally supposed also to be amenable to metrical analysis. In Ponapean, for instance, if a monosyllabic base is heavy, the reduplicant is light (3a–b); if it is light (here including $C_0\breve{V}C$), the reduplicant is heavy (3c–d). McCarthy and Prince (1995: 334) term this situation QUANTITATIVE COMPLEMENTARITY.

(3)
- a. du-duːp ‘dive’
- b. ma-mand ‘tame’
- c. paː-pa ‘weave’
- d. lal-lal ‘make a sound’

[4] A third, mid allomorph *-nto* ∼ *-ntö* is more lexically idiosyncratic and put aside here.

[5] It is unclear what would happen if multiple geminates cooccurred.

1.7 Constituent order

A final grammatical domain in which phonological weight is relevant concerns constituent order in sentences. In particular, many languages, including English, exhibit a general END-WEIGHT preference, meaning that heavier constituents tend to be placed later. This effect is evident in numerous constructional choices in English, some of which are schematized in (4), in which (all else being equal) order B becomes more likely as X becomes heavier (relative to Y, if present) (e.g. Hawkins 1994, Wasow 2002).[6] For example, in (a), as phrase X becomes heavier, placing X after the particle is increasingly preferred; (b) indicates that coordinated phrases tend to be organized from lightest to heaviest; and so forth.

(4)

			Order A		Order B
a.	Particle verbs	e.g.	*picked* X *up*	~	*picked up* X
b.	Coordination	e.g.	X *and* Y	~	Y *and* X
c.	Dative alternation	e.g.	*gave* X *to* Y	~	*gave* Y X
d.	Heavy NP shift	e.g.	*revealed* X *to* Y	~	*revealed to* Y X
e.	Genitive alternation	e.g.	X*'s* Y	~	Y *of* X
f.	Locative alternation	e.g.	*spray* X *with* Y	~	*spray* Y *on* X
g.	Extraposition	e.g.	N Rel-X V	~	N V Rel-X
h.	AP stacking	e.g.	AP-X, AP-Y N	~	AP-Y, AP-X N
i.	PP stacking	e.g.	PP-X PP-Y	~	PP-Y PP-X

A great variety of factors influences such constructional choices, including many non-phonological factors such as frequency, animacy, gender, proximity, givenness, and syntactic complexity (whether measured in words, nodes, etc.; *ibid.*). Independent of these considerations, phonology is also a significant factor. Phonology's contribution can be isolated either by controlling for other factors in a multivariate model (Wright and Hay 2002, Wright et al. 2005, Benor and Levy 2006, Shih et al. 2015) or through experimental design, for instance, a nonce-word coordination task (Bolinger 1962, Pinker and Birdsong 1979, Oden and Lopes 1981, Oakeshott-Taylor 1984, Parker 2002).

The following phonological factors are generally considered to be preferred in the later ("Item B") position, contributing to end-weight (Cooper and Ross 1975, Pinker and Birdsong 1979, Ross 1982, Wright et al. 2005, Benor and Levy 2006). First, item B tends to have more syllables (e.g. *kit and caboodle*; *trials and tributations*; *friends, Romans, countrymen*). Second, item B tends to have a longer vowel (or vowels) (*trick or treat*; *Slip & Slide*; *Tic-Tac-Toe*). Third, item B favors more sonorous codas (*thick and thin*; *kith and kin*; *push and pull*). Fourth, item B favors more obstruent onsets (*wear and tear*; *huff and puff*; *wheel and deal*). Finally, some studies find that item B favors longer onsets (*fair and square*; *meet and greet*; *sea and ski*). Item B may also favor longer codas, but this is not well established (cf. Pinker and Birdsong 1979, Ross 1982).

[6] N refers to "noun," V to "verb," Rel to "relative clause," AP to "adjective phrase," and PP to "prepositional phrase."

All of these factors are consistent with the typology of weight in other domains (stress, meter, etc.). For example, consider the discrepancy between onsets and codas with respect to sonority. In end-weight, greater weight is associated with higher sonority in the coda but lower sonority in the onset. This reversal is exactly what is observed in the stress typology (Gordon 2005). In this sense and others, phonological end-weight arguably reflects bona fide prosodic weight as opposed to mere complexity or duration (Ryan 2013).

2 Some current issues concerning weight

This section touches on five selected current issues in the analysis of weight. The first concerns whether weight is a property of the syllable or interval. The second addresses the weight-bearing capacity of onsets. The third considers highly complex or gradient scales. The fourth touches on the interrelated issues of process-specificity in weight, effects of final position, and the phonetic grounding of categorization. Finally, the fifth addresses the mora as a unit of weight.

2.1 Syllables vs. intervals

Although the vast majority of generative research on weight-sensitive systems since the 1980s takes the syllable (rime) to be the domain over which weight is assessed, this view has been challenged recently by evidence favoring an interval theory of weight (Steriade 2008, 2012), which maintains that (most) weight-based phenomena reflect instead the total vowel-to-vowel interval (or just INTERVAL for short). An interval comprises a vowel and all consonants up until the following vowel (or, if no vowel follows, until the end of the domain).[7] For example, English *skeptical*, syllabified *skep-ti-cal*, contains the intervals *ept*, *ic*, and *al*. Traditionally, a word like *sképtical* is said to receive antepenultimate stress because its penult is light. This analysis is equally compatible with syllables and intervals. With the former, *ti* is light because its rime comprises a single timing slot. With the latter, the criterion for light need only be adjusted to include up to two timing slots, such that the interval *ic* is light.

Despite its recent attention, the interval in precisely this sense is an old idea, older than the modern conception of the syllable. Pāṇini (c. 4th century BCE), for one, defines a short vowel as metrically light (*laghu*) unless it immediately precedes a consonant cluster (*saṃyoga*), in which case it is heavy (*guru*) (1.4.11). The notion remained widespread in the 19th and 20th centuries. Consider e.g. Pipping (1903: 1) on Old Norse: “The morae of a syllable are counted from its vowel to (but not including) the vowel of the following syllable” (translation Gade 1995: 31).[8] On this scheme, bimoraic syllables are light, while trimoraic

[7] In the context of stress, the domain is normally the word. In quantitative meter, the domain is usually much larger, often the line. For example, in a Sanskrit meter in which the line-penultimate syllable must be heavy, we find the ending *caná prá*. Under syllables, most analysts assume resyllabification across words: [ca][ná p][rá]. Intervals would likewise ignore the word boundary: [can][á pr][á].

[8] “Man räknar en stafvelses moræ från och med dess vokal till (men icke med) nästa stafvelses vokal.”

or longer syllables are heavy (*ibid.*).

Steriade (*op. cit.*) adduces several arguments for intervals, of which a partial survey follows. First, the interval rather than the rime (or syllable) appears to be the target of durational invariance, wherein compensatory effects obtain (Farnetani and Kori 1986, Fant and Kruckenberg 1989, McCrary 2004).[9] This research supports, among other things, that a vowel's duration correlates negatively with the duration of the following consonant even when that consonant is the onset of the following syllable. For example, in Italian, [ɲ] is shorter than [ʎ], and the vowel [a] is compensatorily shorter before the latter, though not as short as it would be in a closed syllable (Farnetani and Kori 1986).

Second, intervals are argued to better predict the typology of poetic rhyme. For rhyme systems in which spans are not required to extend to the end of the line, the interval is attested as a minimum domain of correspondence, while the syllable and rime are not. For example, Vergil has rhyming sets such as *Diōrēs*, *ōra*, *clāmōribus*, *honōrem*, *decōrae* etc., in which the stressed VC$_1$ sequence within each word (here, *ōr*) rhymes. This sequence is an interval, not a rime or a syllable. Perhaps no comparable case exists in which the corresponding sequences are required to be rimes or syllables.

Third, intervals predict final VC# to be equivalent in weight to medial VCV, while syllables predict VC# to be heavier than VCV. Steriade suggests that the former prediction aligns better with the typology, and obviates the need to stipulate final consonant extrametricality (i.e. inertness; see Section 2.4) in many systems, as syllables require.[10]

Fourth, intervals but not syllables predict that a vowel immediately preceding another vowel could be treated as lighter than a pre-consonantal vowel. This prediction is borne out by several languages, including Finnish (Karvonen 2008), in which vowels "in hiatus" reject secondary stress (e.g. *érgonòmi.a* vs. *tánanarìve*).

Fifth, intervals predict, apparently correctly, that consonant interludes treated as light (e.g. *ăkra* in Aristophanes' Greek) must be durationally shorter than those treated as heavy (e.g. *ăksa*). Syllabic analysis derives this difference in weight from a difference in syllabification (*ă.kra* vs. *ăk.sa*), but does not require syllabification to reflect durational differences, missing the generalization. A weight distinction between intervals such as *ăkr* and *ăks* could only reflect a durational difference under interval theory because there is no possibility of parsing intervals differently for different clusters; the interval is defined as the maximal VC$_0$ string. Thus, while these two intervals have the same number of segments, interval theory predicts that the lighter interval must be shorter in such cases, evidently correctly, based on preliminary phonetic evidence (Steriade 2008, 2012).

Finally, syllable division judgments are often ambiguous, even while weight-sensitive systems in the same language are invariant. This situation is expected if grammatical systems

[9]Cf., however, Ryan (2014: 314) and references therein, which demonstrates that onset duration also trades somewhat with that of the following vowel, though possibly not to the same extent.

[10]A language with unbounded stress, weight by position, and no extrametricality, such that final VC# is treated as equivalent to VC.CV in any position, would favor syllables over intervals. This situation is uncommon; Yana, for one, may be a case (Sapir and Swadesh 1960).

rely on intervals, which are invariant, immune to complications affecting syllable division, such as the desire to treat each chunk as a well-formed prosodic word.

Experimental and corpus-based evidence for intervals is mixed. Hirsch (2014) supports intervals using a pseudoword stress task in English, in which speakers were asked to read orthographic prompts aloud (e.g. *keefoos*), their stress placements being logged. He found that longer consonantal interludes favored initial stress, even when they could only be parsed as the onset of the second syllable (e.g. more initial stress in *kee.floos* than *kee.foos*), as predicted by intervals (*keefl* > *keef*). Garcia (to appear) likewise finds some support for intervals in the Portuguese lexicon, in which, e.g., a longer penultimate onset results in more frequent antepenultimate stress, consistent with intervals but not syllables. Nevertheless, other experimental and corpus results seem to favor syllables. Olejarczuk and Kapatsinski (2016), testing stress in English pseudowords, argue that their own results depend on the legality of the interlude as an onset, not the duration of the interval. Ryan (2014) analyzes existing disyllables in English, finding that longer final onsets correlate with more frequent final stress, ostensibly contradicting intervals. Finally, when Garcia (to appear) pitted syllables against intervals in omnibus models, the results were mixed, with intervals outperforming syllables in some respects but underperforming in others. For example, increasing onset size in the antepenultimate syllable correlates with greater antepenultimate stress, inconsistent with intervals. Reconciling these various findings remains an area of active research.

2.2 Onsets

A widely repeated traditional view of syllable weight posits it to be a property of the rime (e.g. Halle and Vergnaud 1980). As such, onsets are claimed never to contribute to weight. This view has been challenged by a growing body of evidence since the 1980s. A famous early counterexample was Pirahã, which exhibits the scale $\mathrm{C}_{vcd}\breve{\mathrm{V}} < \mathrm{C}_{vless}\breve{\mathrm{V}} < \mathrm{VV} < \mathrm{C}_{vcd}\mathrm{VV} < \mathrm{C}_{vless}\mathrm{VV}$,[11] such that within the final three-syllable window, the rightmost syllable of the heaviest category available receives stress (Everett and Everett 1984, Everett 1988, Gordon 2005: 608).

Since then, many other putative cases of onset-driven weight have surfaced, not only for stress, but for nearly all of the weight-sensitive phenomena enumerated in Section 1. Topintzi (2010) is the most complete recent survey; others include Davis (1988), Goedemans (1998), Gordon (2005), and Ryan (2014). The presence vs. absence of an onset appears to condition stress placement in three unrelated Amazonian languages, several Australian languages, and at least three other independent cases around the world (*op. cit.*).[12] Onset voicing has been claimed to affect stress placement in at least four unrelated languages. Though there is no clear case of a categorical weight criterion invoking onset complexity (*pace* Gordon

[11] C_{vcd} is a voiced consonant, C_{vless} a voiceless one.

[12] Of the cases enumerated in this paragraph, these have been perhaps the most amenable to reanalysis in non-weight-based terms, such as requiring the head of a foot to be aligned with a consonant, rendering a word-initial vowel extraprosodic (cf. Gahl 1996, Downing 1998, Goedemans 1998).

2005; cf. Topintzi 2010: 223), at least four languages treat geminate onsets as heavier than singletons. Beyond stress, Topintzi (2010) surveys alleged cases of onset-sensitivity from compensatory lengthening (see also Beltzung 2008), prosodic minimality, and tone licensing. Ryan (2014) argues that both onset complexity and voicing can affect weight in quantitative meter. Onsets also appear to influence weight in the context of end-weight. As mentioned in Section 1.7, their behavior in end-weight mirrors the typology of onset weight in other systems. For example, voiceless onsets pattern as heavier than voiced ones in end-weight, agreeing with the stress typology (e.g. Pirahã above) and meter (Ryan 2014: 326).

Onset weight has been further supported in recent years by experimental and corpus-based research. Kelly (2004) and Ryan (2011b, 2014) demonstrate that English stress placement is affected by onset complexity, such that increasingly long onsets (Ø < C < CC < CCC) increasingly attract stress. This trend was established for both the lexicon (controlling for various possible confounds) as well as for pseudowords (under several experimental designs, both visual and auditory), confirming its generality and productivity. Ryan (2014) further argues that the trend is subsegmental, such that (longer) voiceless onsets are more stress-attracting than (shorter) voiced onsets in English, just as in Pirahã. Onset size also correlates with stress in Russian (Ryan 2014), Italian (Hayes 2012), and Portuguese (Garcia to appear). Garcia shows that as the number of word-initial consonants increases, the propensity for initial stress significantly increases with it. This effect holds independently for disyllables and trisyllables, just as in English and Russian (*op. cit.*).

Even analysts who support onsets as possible factors in weight, however, acknowledge that the rime perhaps universally takes precedence over the onset (Gordon 2005: 600, Ryan 2014: 329), suggesting a line of synthesis with the conventional wisdom that only rimes bear weight. This asymmetry is evident, for instance, in the Pirahã hierarchy above, in which branching rimes are uniformly heavier than non-branching rimes; it is only within each rime class that the onset factor emerges. At least two (not mutually exclusive) psychoacoustic explanations for onset weight have been put forth which capture this asymmetry between onsets and rimes. Gordon (2005) focuses on auditory adaptation and recovery. For example, a vowel following a voiceless consonant is perceived as louder than one following a voiced consonant because the transition is more distinct for the former. Ryan (2014), seeking better coverage of complexity effects, proposes that the domain for weight begins not with the vowel/nucleus, but with the p-center, roughly, the perceptual "beat" of the syllable, which approximates the beginning of the vowel but anticipates it slightly for longer onsets. Because all of the rime but only a fraction of the onset are parsed into the p-center interval, onsets are predicted to affect the weight percept more weakly than rimes.

Interval theory (Section 2.1) also predicts non-initial onsets to affect weight, but in a somewhat different sense from the discussion of initial onset effects above. Because every non-initial onset is parsed into an interval with the preceding vowel, the duration of a (medial) onset is predicted to contribute to weight just as much as the duration of a nucleus or coda does. In *skeptical*, for example, the duration of the first interval is the sum of the durations of the nucleus *e*, coda *p*, and onset *t*. In Steriade's (2012) version of interval theory, the initial onset (e.g. *sk* in *skeptical*) is extraprosodic. As such, the initial onset complexity effects discussed in this section are unexpected. Nevertheless, interval theory could in principle be modified to accommodate these effects. The first possibility is to incorporate the initial onset into the first interval (so that, e.g., *skeptical* would be *skept-ic-al*). The second (as raised by Ryan 2014: 330, Hirsch 2014: 11, and Garcia to appear), is to hybridize interval and p-center theory, defining the left edge of the interval as the p-center rather than the beginning of the vowel.

2.3 Rich scales

As suggested above, weight hierarchies can be quite complex, beyond two or three levels. Recent work highlights that highly articulated scales of weight, far from being confined to "exotic" languages such as Pirahã (Section 2.2), are widely evident even in European languages such as English, Russian, Italian, Portuguese, Ancient Greek, Old Norse, and Finnish (Ryan 2011a, 2011b, 2014, Hayes 2012, Garcia to appear). For additional cases, see, e.g., Gordon (2006: 126), de Lacy (2004; cf. 2014), and Crowhurst and Michael (2005).

In many of these cases, gradient scales coexist with binary criteria. Consider stress placement in English disyllables. As traditionally analyzed, a V̆C or VV (or larger) rime is heavy and a word-final consonant is extrametrical. In disyllabic verbs, stress is regularly final (e.g. *protést*) unless the ultima is light (*fásten*); in disyllabic nouns, it is regularly initial (*prótest*; cf. e.g. Chomsky and Halle 1968, Burzio 1994). However, both rules are rife with exceptions. Analyzing the residue reveals statistical subregularities whose productivity can be verified with pseudowords. As discussed in Section 2.2, for example, longer onsets attract stress, diagnosing the scale Ø < C < CC < CCC, which perhaps dissolves even further into featural criteria. Nuclei and codas exhibit similarly fine-grained hierarchies (Ryan 2011b: 165ff).

Gradient weight raises several unresolved issues, of which only a few can be mentioned here. First, it can exist alongside a binary criterion, raising the issue of how the two systems interact and whether they can be unified. In English disyllables, for instance, the binary criterion is a strong predictor, but does not obviously stand apart qualitatively from other structural factors. Second, gradient weight defines an interval as opposed to ordinal scale, the former being quantifiable; the latter, strict. For example, according to one diagnostic, an onset consonant contributes ∼35% as much to weight as a coda consonant in English (Ryan 2014). Interval scales have been analyzed by Ryan, Garcia, and others (*op. cit.*) with numerically weighted constraints. A third issue concerns the level of phonetic detail available to weight-sensitive systems. Insofar as the phonology has access to such detail, it must at least be normalized to abstract away from irrelevant, low-level variation (e.g. Steriade 2009, Zhang 2004). A fourth question concerns whether stress is determined by grammar or analogy. Analogical models determine stress placement in (pseudo-)words by comparing them to their nearest (i.e. most similar) neighbors in the lexicon, while grammars apply broad rules (e.g. Eddington 2000 pro analogy; Ryan 2014: 320 contra).

2.4 Process-specificity, positional specificity, and categorization

One central result of Gordon's (1999, 2002, 2006) typological survey of syllable weight is that weight is not parameterized on a per-language basis, but process-specific, meaning that (a) within a language, the categorization of weight often varies according to the phenomenon and (b) across languages, different phenomena exhibit systematically different typologies. For example, Malayalam stress treats V̆C rimes as light, but its metrics and minimality treat them as heavy. More generally, Gordon shows that disagreement between subsystems within a language is perhaps even more common than agreement, and often reflects predictable discrepancies. Tone licensing, for instance, usually treats V̆T (where T is an obstruent) as light, while stress usually treats V̆T as heavy. Gordon motivates such divergences through the distinct phonetic requirements of each phenomenon: Since pitch is realized on sonorants, tone licensing, unlike stress, typically depends only on the sonorant portion of the rime.

In many languages, word-final position receives special treatment by the stress rule or weight criterion. In particular, stress often ignores a final constituent of some specified level (e.g. syllable, segment, consonant, or coda), which is said to be EXTRAMETRICAL (Liberman and Prince 1977, Hayes 1979a, 1982). For example, Classical Arabic observes the Latin weight criterion discussed above, such that $C_0\breve{V} \Leftrightarrow$ light. Stress then falls on the rightmost heavy syllable, with one exception: Word-final C_0VX (i.e. $C_0\breve{V}C$ or C_0VV) eschews stress, as if it were light. Hayes (1982) invokes segment extrametricality in this case (e.g. *mudárri<s>*, *máktaba<h>*, but *šaríb<t>*).

Extrametricality therefore simplifies the analysis of weight by allowing the criterion to remain uniform in all positions. It is almost always right-edge-oriented (though some have argued for left-oriented cases as well, as in Kashaya; Buckley 1994), an asymmetry that has received at least two phonetic explanations, namely, tonal crowding avoidance (Hyman 1977, Gordon 2001, but cf. Gordon et al. 2010) and final lengthening (e.g. Lunden 2010, 2013, Gordon et al. 2010). The latter refers to the fact that segments near the end of the word are usually pronounced as longer than they would be in other positions, all else being equal (e.g. Wightman et al. 1992). As Lunden (*op. cit.*) observes, the ratio of the durations of V̆ and V̆C is closer to one in the final, lengthened syllable than it is in other positions, a phonetic motivation for the grammar's conflating the two as light in final position alone.

Related to the phonetic grounding of process- and position-specificity in weight is the more general phonetic basis of categorization. Gordon (*op. cit.*) and others (e.g. Broselow et al. 1997) have argued that the selection of a (binary) criterion is at least partly predictable from other phonetic and phonotactic properties of the language. Gordon proposes that languages tend to select criteria that maximize the difference between the average total energy of heavy syllables and that of light syllables, sometimes compromising somewhat to favor phonologically simple (single predicate) diagnostics. Gordon terms these two simultaneous desiderata for categorization PHONETIC EFFECTIVENESS and PHONOLOGICAL SIMPLICITY. He speculates that a third desideratum might favor roughly balanced populations of heavies and lights, but does not pursue it (2006: 169). Another open question with which Gordon (*op. cit.*) does not engage concerns the mechanism by which the proposed optimization of criteria plays out in acquisition and/or diachrony. For example, as a language changes, to what extent are learners willing to stick with an increasingly ineffective criterion in order to be faithful to the stress pattern (etc.) of their learning data?

2.5 The mora

Most scholarship on syllable weight since the late 1980s assumes the mora (μ) as the unit of phonological weight (e.g. Hyman 1985, McCarthy and Prince 1986, Zec 1988, Hayes 1989, et seq.). A light syllable has one mora, a heavy two (some scholars, e.g. Hayes 1989, argue for trimoraic syllables as well). A long vowel is necessarily bimoraic and a geminate consonant necessarily (at least) monomoraic. A coda consonant might be moraic or not depending on whether the language treats V̆C rimes as heavy.

While there is not space here to explore the issue in any depth, some recent work on weight does not adopt the mora. Gordon (2006), for example, employs constraints referring to X slots and features. Some putative problems for the mora include the following. First, weight criteria often differ across processes within a language (Section 2.4), while moraicity is often assumed to be uniform (cf. Hyman 1985, Archangeli 1991, Steriade 1991, and Hayes 1995 for some early responses to this problem). Second, weight hierarchies can be highly complex, beyond two or three levels (Section 2.3). For example, at first glance, the scale V̆ < V̆C < VV appears to be problematic for moras, as VV could only reasonably have two, but outweighs V̆C. Morén (1999) shows that this scale can emerge from constraint interaction, such that codas are only coerced into moraicity when no long vowel is available.

That said, other cases remain challenging. In English, for instance, each additional onset or coda consonant appears to contribute to a syllable's stress propensity (Section 2.3). Progressively longer vowels also appear to correlate with progressively greater weight, beyond the tense/lax dichotomy (e.g. Oakeshott-Taylor 1984). Thus, the problem is not only the multiplicity of levels, but also the different degrees to which different elements contribute. Of course, one could still maintain that at most one coda consonant (perhaps two) can be moraic ("phonological quantity" proper), leaving other, non-mora-based devices to explain the effects of additional onset or coda consonants, the phonetic durations of vowels, and other factors on stress propensity (perhaps terming these effects "prominence").

The question is whether positing this fundamental division of labor is parsimonious and well motivated empirically (see also the discussion of binarity in Section 2.3). Hayes (1995: 271), for example, distinguishes between quantity and prominence along roughly the aforementioned lines, suggesting that only quantity is concerned with the time dimension. But in the English example just offered, arguably all of the factors concern timing. If the first consonant after the vowel is said to affect quantity by virtue of its duration, why not the second, or the third, or onset complexity, or the duration of the vowel? Zhang (2002, 2004) proposes a unified, mora-free model and raises additional objections to the mora in the context of tone licensing, some of which apply to weight more broadly. Another framework in which the mora is abandoned (or orthogonal) is that of Steriadean (Section 2.1) or p-center (Section 2.2) intervals.

3 Conclusion

Weight is relevant to a wide range of phonological and poetic phenomena. It is usually conceived of as a property of syllables (or intervals; Section 2.1), though it may be implicated by phrasal constituents as well (Section 1.7). Scales for weight are most familiarly binary and ordinal, but may also be considerably more fine-grained and/or probabilistic (Section 2.3). Rich scales, phonetic detail, process-specificity, weak but not inert onsets, and other issues raised in Section 2 present challenges for the grammatical representation and manipulation of weight.

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