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Explaining word-final stress lapse

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Abstract

This chapter proposes and examines evidence for a motivation behind the well-known asymmetrical tolerance for stress lapse word-initially versus word-finally across languages. While many binary-stress languages tolerate a stress lapse at the right edge of the word, very few tolerate a stress lapse at the left edge. It is proposed that, in the languages that tolerate a final stress lapse, there is nevertheless a rhythmic alternation present at the right edge of the word, due to the phonetic effect of word-level final lengthening. If final lengthening were able to perceptually contribute to a word's rhythm in cases of final lapse, we would expect this to only be possible when stress in the language has duration as a stress correlate. Evidence from two different sources is shown to support the connection between languages' tolerance of final stress lapse and their use of duration in stress. Drawing on a database of stress correlates, it is shown that languages which tolerate a final stress lapse are extremely likely to have duration as a stress correlate, whereas no such correlation exists for final lapse and the stress correlates of pitch or intensity. Several perception experiments also support this connection: final lengthening was found to be confusable with stress, only if stressed syllables included increased duration. An account is sketched of how this could be captured in an Optimality Theoretic analysis.

1 Introduction

This chapter examines a link between the asymmetric tolerance of word-edge lapse among binary-stress languages and the phonetic realization of stress.* Phonological stress typologies are classically agnostic as to how stress is realized (e.g. Kager 2001, Gordon 2002, Alber 2005, Kager 2005). This chapter, however, proposes that there are differences in the typology depending on the phonetic manifestation of stress. The connection explored here is that the word-edge specific phonetics of final syllables can relate to the rhythmic stress pattern in some languages. Specifically, whether or not a language tolerates a final stress lapse is shown to be correlated with whether the language uses duration in its realization of stress. For those languages that do use duration and tolerate a final stress lapse, the hypothesis is put forward that the final lengthening inherent in the final syllable continues the rhythmic pattern of the word, without the final syllable needing to bear stress.

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Binary-stress languages are those languages with some level of stress occurring (generally speaking) on every other syllable. Typically, such systems are thought of as assigning stresses in words in either a strong-weak (trochaic) pattern, or a weak-strong (iambic) pattern starting from either the left edge ("left-aligned") or the right edge ("right-aligned") of a word. While a distinction can almost always be made between the single primary stress (generally the first or last stress in the word) and the other, secondary, stresses, the discussion here is concerned with the overall alternating patterns and so will conflate degrees of stress under the term "rhythmic stress." Rhythmic stress can be interrupted by languages allowing adjacent unstressed syllables (stress lapse) or adjacent stressed syllables (stress clash). A typical reason for stress clash occurs in weight-sensitive languages where heavy syllables often draw a stress, which may then occur adjacent to either a rhythmic stress or another stress-drawing heavy syllable. Typological work on rhythmic stresses is often confined to quantity-insensitive languages (where even if heavy syllables exist, they do not affect the stress pattern) and the stress patterns that quantity-sensitive languages employ in words with all light syllables. Clash is fairly rare in these systems (Gordon 2002) but lapse is not uncommon.

The binary stress pattern may be interrupted by lapse either adjacent to the primary stress (what Gordon 2002 called "internal lapse") or at a word-edge ("external lapse"). Cases of internal lapse classically arise when the primary stress is affiliated with a different word edge from the secondary stress alternations. For example, verbs in the Austronesian language Lenakel bear primary stress (σ́) on the penult and have secondary stress (σ̀) on the initial syllable and every other syllable thereafter, which can lead to word-internal lapses, as in *tɨ̀.na.gà.ma.ɾɔl.géy.gɛy* 'you (pl.) will be liking it' (Lynch 1978: 19). Such cases are not relevant to the discussion here, as we will be looking at stress patterns that occur when the primary stress is part of the same rhythmic pattern as the secondary stresses. In such languages we could theoretically get an external lapse on either side; however, in practice, initial stress lapses are extremely rare.[1] By contrast, cases of final lapse in binary stress languages are notably common. Some examples are given in (1). (Note that here and elsewhere, feet are not marked, as the focus is on the rhythmic pattern, although trochaic and iambic foot types will sometimes be referred to in order to concisely describe stress patterns.)

(1) Examples of binary-stress languages that allow final lapse

English	jù.nɪ.v̩í.sɪ.ɾi	'university'	
Pintupi	pú.liŋ.kà.la.tʲu	'we (sat) on the hill'	Hansen and Hansen (1969)
Hixkaryana	tóh.ku.rʲéː.ho.na	'to Tohkurye'	Derbyshire (1985)
Finnish	ó.pet.tè.le.mà.na.ni	'as something I have been learning'	van der Hulst *et al.* (2010)

The opportunity does not even arise, of course, in languages with regular penultimate stress, like Tuvaluan, which places primary stress on the penult (and secondary stresses on every other syllable preceding it; Besnier 2000). But others, like Maranungku, which has the

[1] The known case is Winnebago, which assigns primary stress to the third mora from the left and secondary on every other mora thereafter, as in *ha.ki.rú.ʤik.ʃą̀.nąą* 's/he pulls it taut (declarative)' (Hale and White Eagle 1980).

pattern of syllabic trochees from the left (like Pintupi and Finnish, shown above), will carry the alternating rhythm through to the end (unlike Pintupi and Finnish) and so prevent a final lapse, e.g. *láŋ.ka.rà.te.tì* 'prawn' (Tryon 1970).

The commonness of final stress lapse in rhythmic stress languages seems surprising, given that internal lapse is relatively rare and initial lapse is exceedingly rare. The following sections explore the prevalence of word-final stress lapse and offer an explanation for why it is so widely tolerated.

2 Approaches

Final stress lapse can be seen as a consequence of forces known to influence stress patterns. Related to the lapse-asymmetry is the fact that many languages never allow stress on the word-final syllable, which is captured by excluding the final syllable from stress-related rules or requirements. This tendency is generally referred to either as *extrametricality* (Liberman and Prince 1977, Hayes 1982) or as *nonfinality*, after the Optimality Theory (henceforth, OT) constraint, which either forbids the final syllable from being included in a foot (the more direct instantiation of extrametricality; Prince and Smolensky 1993) or forbids a stress from occurring on the syllable at the right edge of the word (Walker 1996). Rhythmic stress systems with extrametricality/nonfinality will naturally lead to instances of final stress lapse. Further, in accounts of the stress typology that use feet, final lapse naturally falls out as the effect of footing binary trochees from the left, since a final syllable will be left over in words with an odd number of syllables: (σ́σ)(σ̀σ)σ. There are reasons to think that the tolerance for final stress lapse goes beyond these factors, however.

If the final syllable tendency to be excluded from any stress-related rules or structure accounts for the prevalence of final stress lapse, then we should expect to see the final syllable avoided in right-aligned stress systems as well as left-aligned ones. That is, we expect to see many languages that are like Latin, where a trochee is placed one syllable in from the right edge: σ(σ́σ)σ. The StressTyp database (Goedemans and van der Hulst 2014),[2] however, yields just seven such cases out of the 35 languages that foot trochees from the right, with a rightmost headfoot. This contrasts sharply with the 22 trochee-from-the-left, headfoot left, languages that are listed as tolerating final stress lapse out of the 37 total of the type.[3] In Gordon's (2002) typology of quality-insensitive stress patterns, rhythmic stress languages in which stress falls on the initial syllable and every other syllable following excluded the final syllable in 14/29 cases.[4] The comparison of extrametricalty/nonfinality affecting 20 percent of right-aligned trochees, compared to 48∼62 percent of left-aligned trochees, indicates that final syllable exclusion may not be the only force at work.

[2]The searches referencing the StressTyp database reflect an earlier version of the database, which has since been supplanted by StressTyp2.

[3]The first StressTyp database only allowed two simultaneous search parameters. StressTyp1 contained 83 languages in which Direction=L(eft) and RhythmType=tr(ochee) and 60 in which Direction=R(ight) and RhythmType=tr. Both sets were then sorted though to exclude cases with nonrhymthmic stress and with an opposite-head headfoot. The later filter was to exclude cases of bidirectional footing, which might result in word-internal lapse. An additional 12 trochee-from-the-left languages met the criteria, but the acceptability of final stress was not clear.

[4]Excluding three languages where final stress is variable.

Nor can the prevalence of final stress lapse be put down to the natural consequence of footing an odd-syllabled string. A language like Pintupi could continue the alternating rhythm if it allowed degenerate feet, as in: (σ́σ)(σ̀σ)(σ̀). Viewing the difference as a choice of whether to allow a single syllable to form a degenerate foot when doing so would continue the rhythmic pattern, we would expect to find languages behaving similarly at both the left and right edges. There are only eight languages (identified looking at both StressTyp and Gordon 2002) which assign stress on the final and every other syllable preceding and all eight stress the initial syllable when a stress lapse would otherwise result: (σ̀)(σσ̀)(σσ́). So while half or fewer of trochee-from-the-left systems require a degenerate foot, all iamb-from-the-right systems require one. (This latter observation is well known from Kager 2001.) This indicates that there is a pressure for alternating stress word-initially that is not there to the same extent word-finally. Thus we see that while both extrametricality/nonfinality and the tension between alternating stress and ideal feet can lead to final stress lapse, the typological distributions indicate that neither is sufficient to explain the prevalence of final stress lapse.

Theoretical accounts of the stress typology couched in OT include asymmetric constraints in order allow word-final, but not word-initial lapses. The basic tension in OT approaches is between *Lapse and NonFinality, which (for cases where a stress falls on the antepenult in a binary-stress system) gives the choice of continuing the rhythm through the final syllable, despite the pressure of NonFinality, or tolerating a stress lapse in order to keep stress off the final syllable. In Gordon's (2002) grid-based account of the stress typology, his constraint Align Edges requires that both the initial and the final syllable bear stress, but a higher ranking of the asymmetric constraint NonFinality will force the word-final syllable to not satisfy Align Edges. Since there is no constraint to force stress off a word-initial syllable the system cannot generate a word-initial lapse. In his foot-based typology Kager (2001, 2005) uses an OT constraint that directly licenses word-final lapses: Lapse-at-End, defined as "[any] lapse must be adjacent to the right edge." (The constraint set of Kager 2001, 2005 also includes Lapse-at-Peak to allow word-internal lapses adjacent to the primary stress.) The account of Alber (2005) has a more indirect asymmetric constraint to allow word-final stress lapse. Her typology includes only leftward alignment of feet, excluding rightward alignment entirely. Thus, leftward alignment can generate rightward trochees with a final lapse, (σ́σ)(σ̀σ)σ, and leftward iambs without an initial lapse, (σ̀)(σσ̀)(σσ́),[5] but since there is no rightward alignment there is no way to generate an initial lapse, σ(σσ̀)(σσ́). In van der Hulst's (2014) account of the stress typology encoded as rhythm parameters, final lapse results from systems where secondary stresses ('rhythm' in van der Hulst's system) 'echo' a left-aligned primary stress ('accent') but stop short due to NonFinality. The mirror image, with an initial lapse, cannot occur however, because there is no parameter to exclude the initial syllable from the word rhythm, and so the alternating rhythm will always pervade the left edge of the word.

Clearly, the final syllable tends to be behave differently, in a way that is not mirrored by the initial syllable. The theoretical accounts summarized model this behavior, but they do not explain why the asymmetry exists. As noted, nonfinality is not sufficient motivation for the difference in word edges, as we see it occurring more frequently in systems that can be

[5]Despite the fact that pre-OT analyses would treat it as being footed from the right, this foot construction actually requires leftward alignment in OT (Crowhurst and Hewitt 1995).

described as assigning stress from left to right.

This chapter takes a different kind of approach by looking at evidence that languages' tolerance of final stress lapse is linked to their phonetic properties. Languages that allow a final stress lapse are predicted to have a durational increase in their stressed syllables and also have word-level final lengthening. In such cases, the phonetic increase in duration due to final lengthening may allow the rhythmic pattern that has been realized with duration-cued stress to be perceived as continuing through the final syllable, without the final syllable actually bearing a stress. While this approach is not incompatible with the OT accounts discussed, it could be more directly modeled, which will be addressed in the conclusion.

Stressed syllables commonly stand out perceptually because of their longer duration, higher intensity (loudness),[6] and/or higher pitch.[7] Different languages use different combinations of these phonetic cues. For example, the Trans-New Guinea language Awara uses intensity and pitch (Quigley 2003). The Australian language Gayo uses duration and pitch (Eades 2005), and the Panoan language Matsés uses duration and intensity (Fleck 2003). Languages may have only one suprasegmental correlate, as in the Australian language Nhanda which uses only duration (Blevins 2001), or use all three, as in the Austronesian language Tuvaluan (Besnier 2000).

Independent of stress, both the left and right edges of a word are subject to phonetic augmentation. The initial syllable exhibits initial strengthening, a cross-linguistic phenomenon in which the onset of the initial syllable shows increased duration (e.g. Oller 1973) and a stronger articulation (e.g. Keating *et al.* 2003). A syllable at the right edge of the word is subjected to final lengthening, a cross-linguistic phenomenon (although its degree varies by language, and it can be suppressed in a language [e.g. Gordon *et al.* 2010]) that occurs at the right edge of prosodic boundaries: at the word, phrase, and utterance levels. Word-level final lengthening was found by Lindblom (1968) for Swedish and by Oller (1973) for English. It has been demonstrated that final lengthening affects the rime of the syllable preceding the prosodic boundary (Crystal and House 1990, Wightman *et al* 1992). This difference in phonetic augmentation at the left vs. right edge of the word provides a potential explanation for the tolerance of stress lapse word-finally, if the phonetic lengthening inherent in the position can be perceived as part of the rhythm of the word.

Unstressed syllables exhibiting final lengthening have a phonetic similarity to stressed syllables in languages which use duration to realize stress. The idea explored here is that the word-edge phonetics of the right edge can contribute to the rhythm of the word in rhythmic stress languages under certain circumstances. The remainder of this chapter looks at two sources of evidence for a connection between a language's phonetic realization of stress and tolerance of a final stress lapse and then sketches out a theoretical implementation. The following section looks at typological evidence for this connection and then the section following turns to evidence from perception experiments.

[6]There are different kinds of loudness, and the one that may actually be most reliable as a stress correlate is spectral tilt (Sluijter and van Heuven 1996), which involves increased loudness of certain frequencies rather than overall. Since most accounts still reference intensity, no distinction will be made here.

[7]The effects of sentence-level intonation are known to be confused with the realizations of word-level stress in many cases (Gordon 2014). Since the focus here is not systems that use pitch, this confound is noted but no attempt is made to disambiguate the source of reported higher pitch on stressed syllables.

3 Database

If the possibility of final lengthening being perceived as a word-level prominence explains the relative acceptability of word-final stress lapse, we would expect to find a correlation between whether a language allows a final lapse and whether it has duration as a stress correlate. We can look for such a correlation using Lunden and Kalivoda's (2016) online, on-going compilation of languages' reported stress correlates.

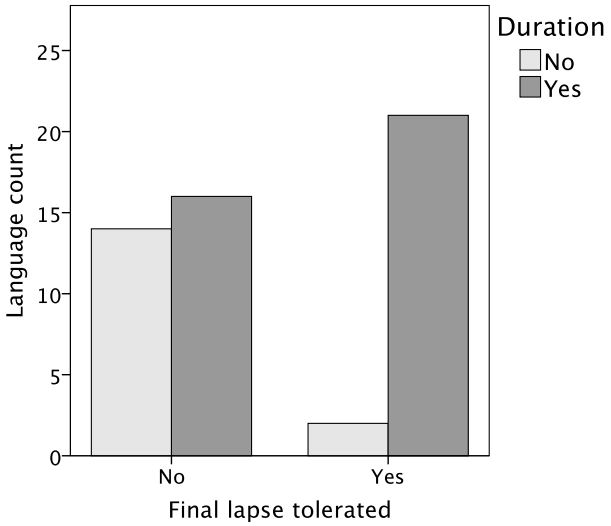
The database currently contains information for 53 languages with binary stress, from 26 different families, for which information on both the stress pattern and the acoustic correlate(s) of stress is available. The database includes languages with acoustically measured correlates whenever the information is available, but relies mainly on the information in published grammars and theses and occasionally information solicited directly from linguists familiar with the language. Languages are categorized as tolerating a final lapse as long as they allow a final lapse to occur in some forms. For example, English is listed as tolerating final lapse because of words like *A.mé.ri.ca* even though many words without a final stress lapse also exist (e.g. *Mà.ssa.chú.setts*). Although the hypothesis that final lengthening contributes to the rhythmic pattern also depends on the presence of word-final lengthening in a language, this information is almost never mentioned in grammars. It therefore is not possible to consider as a factor statistically.[8] Further, the phonetic cues to primary and secondary stress can be different, but it is rare that they are discussed separately, and therefore the database does not distinguish between them. (The question of which stress-level cues are most relevant for the proposed theory will be discussed in Section 5.) For each language description with stated stress cues, the question is asked, for each of the possible correlates, whether it is claimed to play a role in the realization of stress in the language, and coded accordingly.

The database encodes only suprasegmental cues, and so does not include whether vowel quality is a factor in stress, mainly because vowel reduction is not usually included in descriptions of the realization of stress. As we will see in Section 4, however, the vowel quality difference between stressed and unstressed syllables can be very important. Flemming (2005) proposes that vowel quality and duration are inherently linked, where vowels will only have time to be fully realized when there is sufficient duration. If the duration and vowel quality are consistently interconnected in this way then we potentially do not need to encode them as separate stress correlates, although systematic phonetic evidence is needed to show their interdependence across languages.

We find a striking imbalance when we examine the correlation between tolerance of a final stress lapse and the use of duration in the stress correlate database. Twenty-one out of 23 of the languages that can tolerate a final stress lapse use duration as a cue to stress. On the other hand, languages that do not tolerate a final stress lapse are no more or less likely to cue stress with duration. This distribution is shown in the graph in (2).

[8] Domain-final lengthening (generally at the phrase level) has been robustly found across languages (see Barnes 2002: 118-19 for citations) and is assumed to be universal phenomenon, albeit one that varies in degree by language. Word-level final lengthening has been less extensively documented; however, it falls within the scope of domain-final lengthening (as the phonological word is a domain) and so can reasonably be assumed to occur generally. If in fact word-level final lengthening is not typical, it is also possible that a word-final effect is found on analogy to phrase-final lengthening (Gordon *et al.* 2010).

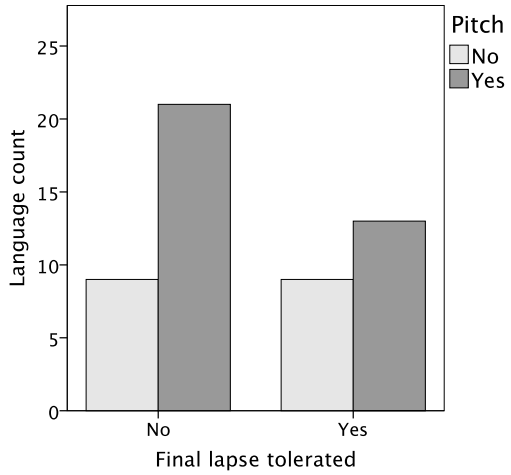
(2) Correlation between final lapse tolerance and duration as a stress correlate



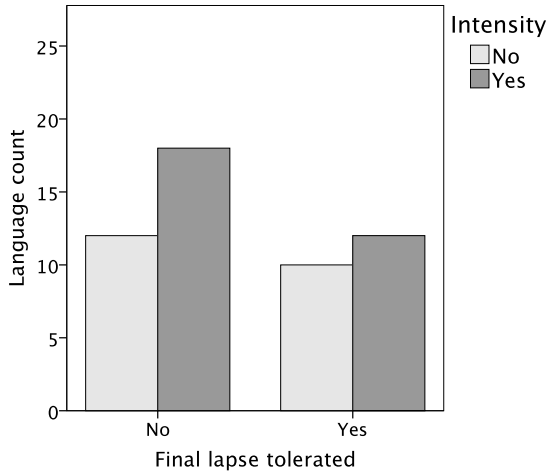
This is what would be expected if the use of duration in stress were, in essence, licensing final stress lapse. On the other hand, if the use of duration as a stress cue were in no way linked to the tolerance of final stress lapse, then we would expect duration to be equally likely to be used as a stress correlate whether a language tolerates a final stress lapse or does not. This is exactly the type of correlation-less distribution we see if we look at pitch or intensity and the tolerance of final stress lapse.

(3)

a. Final lapse tolerance and use of pitch



b. Final lapse tolerance and use of intensity



In both the cases of intensity and pitch, languages are no more or less likely to use these stress correlates based on whether or not they permit a final stress lapse, and thus the properties seem to be independent of each other. A binomial logistic regression shows a significant correlation between whether a language allows a final lapse and whether it uses duration as a cue to stress (Wald $\chi^2 = 6.616$, $p = 0.010$).[9] There is no such correlation for pitch (Wald $\chi^2 = 0.111$, p=0.739) or intensity (Wald $\chi^2 = 0.002$, p=0.968).[10]

Looking at the distribution of duration in (2), we notice that only two languages that tolerate a final lapse fail to have duration as a stress correlate.[11] However, in seven cases, the final lapses were extremely restricted, occurring only with suffixes, or, in some cases, only with a particular suffix. For example, the Arawakan language Ashéninka Perené has primary stress on the penultimate syllable with secondary stress on alternating preceding syllables, but no affixes bear secondary stress (Mihas 2010). If we recategorize these seven cases as not tolerating a final lapse (since the cases where they do so are morpheme-dependent) then we find that 15 out of the 16 languages that tolerate final stress lapse use duration as a correlate of stress (as do 22 out of the 37 that do not tolerate a stress lapse). Running the same full model, the results are unchanged: the use of duration significantly correlates

[9]Of the languages that both tolerate a final stress lapse and use duration, four are Germanic languages (Dutch, English, German, Norwegian), which is the only potential case of closely related languages weighting the results. If only one of the five is included, the correlation for duration is still significant (Wald $\chi^2 = 5.791$, $p = 0.016$).

[10]A single binomial regression was run with FINAL LAPSE (tolerance) as the dependent variable and DURATION, INTENSITY, and PITCH as fixed factors. The reported p-values are those of the fixed effects.

[11]It is perhaps interesting to note that duration is not expressly ruled out as a correlate in the description of either language. One language, Anejom̃, is described as manifesting stress through pitch and intensity. However, it is also noted that, "For some speakers, or in some styles of speech, either the vowel and/or the consonantal coda of the stressed syllable may be slightly longer than in unstressed syllables" (Lynch 2000: 24), raising the possibility that duration actually is a stress correlate. The second language is Apurina, where the referenced correlate statement is "Stress is usually accompanied by a slight rise in pitch" (Pickering 1971), allowing an interpretation that there is another correlate of stress, given to be inherently part of the stress, which pitch accompanies.

with final lapse tolerance (Wald $\chi^2 = 4.076$, p=0.044), whereas neither the use of pitch nor intensity does (Wald $\chi^2 = 2.598$, p=0.107; Wald $\chi^2 = 0.514$, p=0.474). The robust correlation found between final lapse tolerance and a language's use of duration as a stress correlate supports the proposal that rhythmic stress languages do avoid a lapse in rhythm at either word edge, given that final lengthening serves to continue the rhythm through the end of the word in languages that realize stress through duration (and assuming the presence of final lengthening). The fact that there are very few rhythmic-stress languages which both tolerate final stress lapse and fail to use duration means we are no longer faced with the huge imbalance between initial lapse and final lapse typologically: they are both attested but quite rare.

We also see that languages without final lapse are equally likely as not to have duration as a stress correlate. This is not unreasonable, because many of the no-lapse-allowing languages with duration have either penultimate stress (e.g. Lenakel; Lynch 1978) or stress that varies between the penult and the final (e.g. Pashto; Tegey and Robson 1996) and so there is no opportunity for a final lapse to occur. Therefore we do not want to say that a language will tolerate final stress lapse if it uses duration as a stress correlate; rather, we can conclude that those languages that allow a final stress lapse are highly likely to use duration as a stress correlate. This supports the hypothesis that a final stress lapse is tolerated by many languages because the duration inherent in the final syllable is reminiscent of (one of) the stress correlate(s) in the language, giving the perception of rhythmic alternation even in the absence of phonological stress.

4 Perceptional rhythm

If rhythmic-based stress that is cued by duration can be perceptually continued through an unstressed syllable with final lengthening, then we should be able to see experimental evidence of this. The results of three new perception experiments (and reference to one presented previously) which address this prediction are shown. The general setup of the experiments is consistent: subjects were played auditory stimuli consisting of five-syllables strings that varied in strength, e.g. BAbaBAbaBA (where capitals indicate stressed syllables) and were asked, for each string, whether it was "alternating" or "not alternating." While BAbaBAbaBA is clearly alternating and BAbaBAbaba is clearly not alternating, the question of interest is how subjects would categorize strings in which the final syllable in a BAbaBAbaba string reflected word-final phonetics.

4.1 Methods

The stimuli and procedure that are common to all three perception experiments are given below. The participant information and experiment-specific stimuli are given in the subsequent experiment-specific subsections.

4.1.1 Stimuli

The experiments used five types of syllable strings, the syllables for which were made with the speech synthesizer MBROLA (Dutoit *et al.* 1996), using American male voice us3.

The syllables [bɑ], [bi], and [bu] were created for stressed syllables, with corresponding [bə], [bɪ], and [bʊ] in non-final unstressed syllables. Pitch was made to peak at 140 Hz in stressed vowels (20 percent of the way through) and at 120 Hz in basic unstressed vowels. Intensity was manipulated in Praat (Boersma and Weenink 2014), where unstressed syllables were multiplied down (0.5 of original) and then the syllables were concatenated into strings. Beyond the basic unstressed syllable described, two additional unstressed syllables with word-edge phonetic characteristics were also created. In order to simulate initial strengthening, syllables were given a pitch that peaked at 130 Hz (20 percent of the way through the vowel) and an intensity higher than that of other unstressed syllables (multiplied down 0.75, rather than 0.5). To simulate word-final phonetics, the full vowel quality was used and vowels were 120 ms.[12]

Five different types of syllable strings were constructed: fully alternating strings, strings with initial lapse, strings with initial lapse but with an initial syllable with initial-strengthening, strings with final lapse, and strings with final lapse but with a final syllable with final-lengthening. Each of these string types were constructed with the three different vowels and replicated four times in the experiment, with the exception of the fully alternating strings, which were replicated eight times, for a total of 72 strings all together.

4.1.2 Procedure

Experiments were run through Amazon's Mechanical Turk, via ibex (Drummond 2014). Turkers were required to pass an audio qualification test before they were allowed to do an experiment. The qualification gave them alternating and not alternating syllable strings (based on the syllable 'da'). They were told the answers to the first two and then asked to categorize eight further strings, none of which included any syllables with word-edge characteristics. Subjects who qualified (by getting at least nine out of ten correct) and completed an experiment received $1.00. Each subject's responses to the 24 fully alternating test strings were checked and the data from subjects who failed to identify over two-thirds of these strings correctly was discarded, since being able to correctly identify truly fully alternating strings is a prerequisite to deciding whether strings with final lengthening should be categorized the same way.

4.2 When duration is a cue to stress

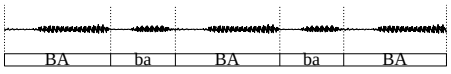
4.2.1 Experiment 1a

The first version of the experiment was set up to test whether syllables with final lengthening are perceived as alternating when stressed syllables are longer than unstressed syllables. The phonetics of the syllables were as described above, with stressed syllable vowels being 120 ms and non-final-lengthened unstressed vowels 60 ms. Thus, unstressed lengthened final

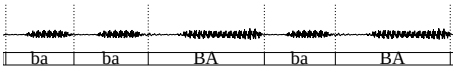
[12]The phonetic characteristics of the syllables were based on a production study of English speakers that had CV syllables in four different positions: stressed word-medial, unstressed word-medial, unstressed word-initial, and unstressed word-final. Final syllables were found to be lengthened and to have a fuller vowel quality. The test vowels were also /ɑ, i, u/ and their pronunciations word-finally were different from other unstressed vowels, being more similar to, or, in some cases, not different from, the quality of the stressed vowels (Lunden, in prep).

syllables had the vowel quality and duration of stressed syllables but the pitch (which fell to 110 Hz) and intensity of unstressed syllables. The waveforms of the stimuli are shown in (4) along with the terms that will be used to refer to each of them. Note that while there are two forms with initial lapse and two forms with final lapse, in each case the term is used to refer to the form without phonetic edge augmentation. The augmented form is referred to as the "*. . . test*" form as these are the strings that of interest; specifically, whether responses to them differ from those to the plain lapse strings.

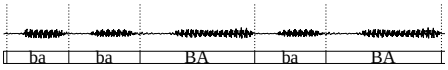
(4) Experiment 1a stimuli



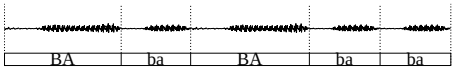
alternating (no lapse)



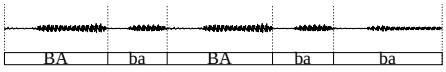
initial lapse (plain initial lapse)



initial test (initial lapse with initial strengthening)



final lapse (plain final lapse)

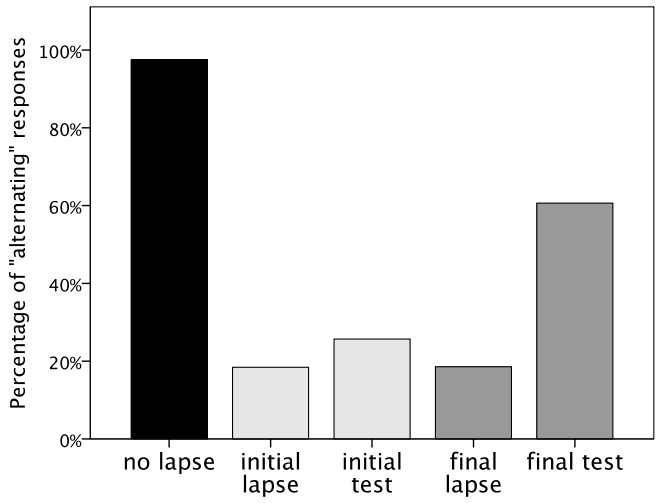


final test (final lapse with final lengthening)

We can judge whether or not final lengthening does in fact continue the rhythmic pattern based on a three-part criteria. First, we should see a notable increase in "alternating" responses in strings with stress lapse but final lengthening (*final test* strings) over strings with final lapse and no final lengthening (*final lapse*). Second, the percent of "alternating" responses for final test strings should be around or above 50 percent, indicating that it is at least confusable with truly alternating strings. (This is separate from the first requirement because it might be the case that *final lapse* strings were heard as alternating 50 percent or more of the time.) Third, the increase between *final test* strings over *final lapse* strings should be notably greater than any increase between strings with initial lapse but initial-strengthening (*initial test*) and strings with initial lapse and no strengthening (*initial lapse*).

Sixty-one monolingual native English speakers took the experiment (male=28; mean age=33). The percent of "alternating" responses for each string type is shown below in the graph in (5).

(5) Percentage of strings identified as alternating: Duration as a stress correlate



It is evident that *no lapse* strings were overwhelmingly correctly identified as alternating, and that the mistaken categorization of strings with a stress lapse as being alternating is fairly low and consistent across string types, with the exception of those with final lengthening.

The results of the *final test* strings satisfy all three criteria laid out above. They are indeed significantly more likely to be perceived as alternating than *final lapse* strings ($p < 0.001$, pairwise comparison as part of a binomial logistic regression with STRING TYPE as the fixed factor). They are identified as alternating 60.7 percent of the time, well over the 50 percent confusability threshold. And the increase in "alternating" responses due to the final edge syllable is clearly much greater than the increase due to the initial edge syllable. Therefore we conclude that we are seeing results consistent with the unstressed-but-lengthened final syllable continuing the alternating rhythm.

It is worth examining the data further to see whether the mixed responses to *final test* strings is due to varying answers across subjects or whether it is in fact due to a binomial distribution within subjects.[13] While 49.2 percent of the subjects usually classified the final test strings as alternating (three-fourths of the time or more), only 26.2 percent rarely did (one-fourth of the time or less). The remaining 24.6 percent varied their responses, indicating that 73.8 percent of subjects found *final test* strings either confusable with *no lapse* strings or in fact generally heard them as alternating. The fact that close to three-fourths of the subjects found them at least confusable with *no lapse* strings indicates that the high number of *final test* strings identified as alternating is not due to a few of the subjects always labeling them as such, but rather was a more general perceptual categorization.

There were some differences in responses by vowel type but all vowel types showed essentially the same distribution of responses. One difference is that initial lapse, with and without initial strengthening, was more likely to be identified as alternating if the stressed vowel was [ɑ]. The increase in "alternating" responses in (5) for *initial test* strings is in fact due to the [ɑ] strings: there is no significant increase in [i] or [u] strings ($p = 0.584$, $p = 0.258$). All *final lapse* strings were equally likely to be identified as alternating, regard-

[13]My thanks to Angeliki Athanasopoulou for raising this question.

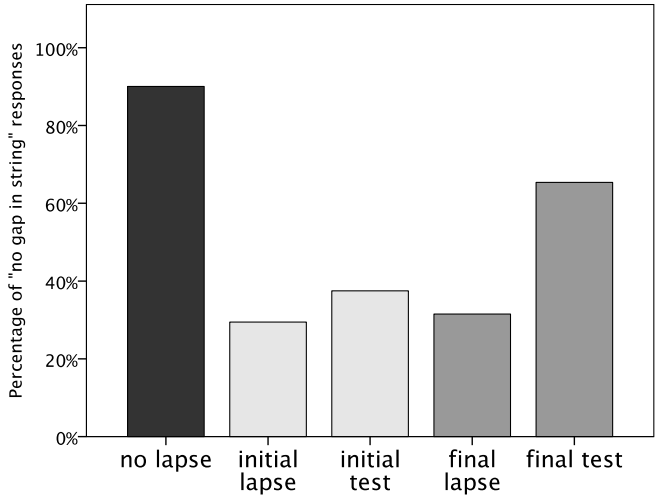
less of the vowel. While the increase in "alternating" responses for *final test* strings varied by vowel (all are significantly different from each other; $p < 0.001$), for all three vowels there is a significant increase in *final test* strings identified as alternating over the *final lapse* strings ($p < 0.001$ within each vowel). Therefore, although we see some magnitude differences, the crucial finding (final syllables with edge phonetics can have a rhythmic effect) holds for all three vowels.

4.2.2 Experiment 1b: Deschenes *et al.* 2012

The final vowels in *final test* strings were like the stressed vowels in both duration and vowel quality, but unlike stressed vowels in pitch or intensity. The phonetics of the syllables, including the unstressed syllables with final lengthening, were based on an production experiment with native English speakers. Because the final vowel quality of the final unstressed syllable in this production experiment was generally in-between that of stressed and unstressed pronunciations of the same vowel, we might be concerned that using the full vowel quality of stressed syllables in word-final, unstressed syllables (as a "slightly reduced" vowel could not be produced in the synthesized stimuli) was in fact what caused the high percentage of "alternating" responses to the *final test* strings. However, Deschenes, Kalivoda, and Lunden (2012) found the same pattern of responses to the same types of stimuli constructed using syllables of the relevant types extracted from the English production experiment.

The 44 subjects (male=15, mean age=20) in the Deschenes, Kalivoda, and Lunden study were students at the University of Georgia who received $5 for their participation. They heard the same types of stimuli (strings of repeated syllables), where the stressed syllables were originally produced with stress, the plain unstressed syllables were word-internal syllables that were unstressed, and the edge syllables were the actually produced unstressed word-initial or word-final syllables in the production experiment.

(6) Percentage of strings identified as alternating: Stimuli constructed from real speech (Deschenes *et al.* 2012)



As can be seen, we see essentially the same distribution of responses as was found with

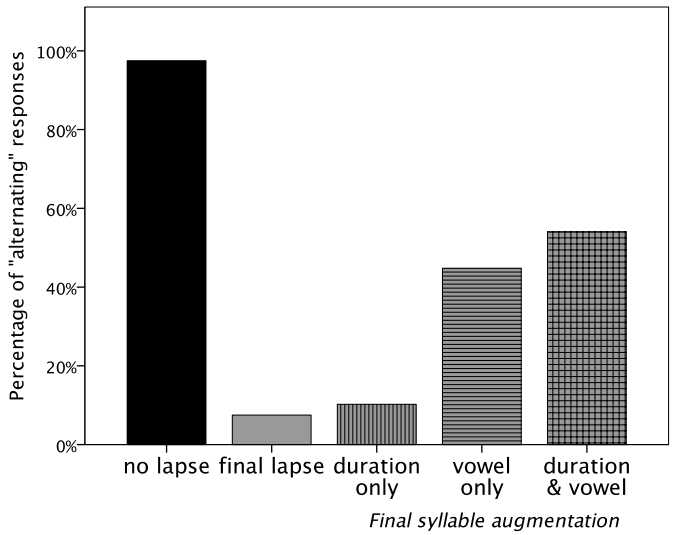
the synthesized stimuli, and the *final test* strings were identified as alternating 65.4 percent of the time, similar to the 60.7 percent of "alternating" responses with the synthesized *final test* strings. Thus, we can conclude that the use of the full vowel quality used in stressed syllables in the unstressed word-final syllables is not what caused the notable number of "alternating" responses in the experiment with synthesized stimuli.

4.2.3 Experiment 2

Having established that the unreduced vowel quality is not inappropriate for the final vowels in *final test* strings, we want to investigate what the individual effects of final lengthening and vowel quality are on final unstressed syllables. In the two experiments discussed, *final test* strings differ from *final lapse* strings in two ways and we would like to be able to disentangle the effect of duration and vowel quality. The working hypothesis is that the duration due to final lengthening is the cause of the perception of *final test* strings as being alternating. We will see, however, that when final lengthening is present without the quality of a full vowel, such strings do not typically get identified as alternating.

For this experiment, again run with synthesized stimuli on Mechanical Turk, only *no lapse*, *final lapse*, and *final test* strings were used, with three different kinds of phonetic cues in *final test* strings. One set had lengthened vowels but the vowel quality of unstressed syllables (*duration only*), a second had the duration of unstressed vowels but the vowel quality of stressed syllables (*vowel only*), and a third was like the final test strings in the first experiment, with the duration and vowel quality of the stressed syllables (*duration & vowel*). The subjects were 48 monolingual native English speakers (males=20; mean age=35).

(7) Percentage of strings identified as alternating: Different word-final phonetics



Surprisingly, we see that lengthening alone does not show a significant increase in "alternating" responses over *final lapse* strings ($p = 0.065$). While we see a significant jump in the percent of strings identified as alternating between *final lapse* and *vowel only* strings ($p < 0.001$), the percentage of alternating responses to *vowel only* strings is 44.8 percent,

below the 50 percent threshold of confusability. It is only when final syllables have both the duration and the vowel quality of stressed syllables that we see the the percent of alternating responses being both significantly greater than those for the final lapse strings ($p < 0.001$) and reaching the threshold of confusability, with 54.0 percent "alternating" responses.

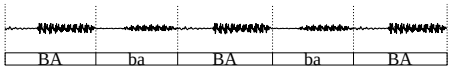
We have seen support for the idea that word-final phonetics can contribute to the perception of rhythm when stress is cued through duration. However, at least for English speakers, it seems that there are two crucial phonetic aspects to a word-final syllable: duration and vowel quality. The prediction is that a language without stress-based vowel reduction could get the rhythmic effect from final lengthening alone. But if vowel quality in fact piggybacks, so to speak, on duration, we might expect any language with duration-cued stress to show some degree of reduction in unstressed syllables and less or no reduction in unstressed word-final syllables.

4.3 Experiment 3: When duration is not a cue to stress

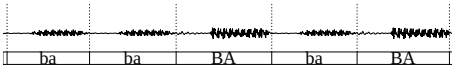
We have seen that the phonetic characteristics of final vowels in English can give the impression that the stress-based rhythm of the word is continued through the end of a word that ends in two unstressed syllables. The preceding discussion has focused on the phonetic characteristics of the final syllable that make this possible. Now we want to turn to look at the rhythmic properties of the word that are at issue. In Section 3 we saw that very few languages that did not use duration as a cue to stress tolerated a final stress lapse. This is consistent with the hypothesis at hand: even though final lengthening is presumably present in non-duration-cued stress languages, it does not continue the rhythm of the stress system.

In order to test this perceptually, new syllables were created in MBROLA that had the pitch, intensity, and vowel quality of the previously created stressed syllables, but were not longer than unstressed syllables. The vowel quality difference between stressed and non-final unstressed syllables was maintained. The waveforms for experiment stimuli are shown in (8).

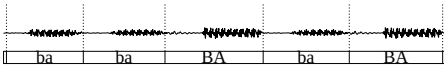
(8) Experiment 3 stimuli



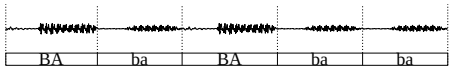
alternating (no lapse)



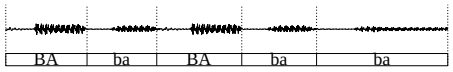
initial lapse (plain initial lapse)



initial test (initial lapse with initial strengthening)



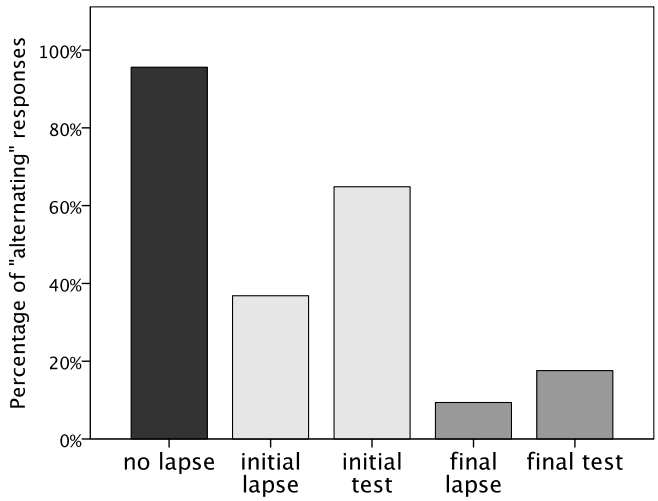
final lapse (plain final lapse)



final test (final lapse with final lengthening)

These stimuli therefore had non-duration-based rhythm. The only longer vowels came from the final syllables in the *final test* strings. The question was whether the final-lengthened syllables would be heard as contributing to the rhythm of word when the stress-based rhythm was not duration-based. Fifty-five monolingual native English speakers took the experiment through Mechanical Turk (male=35; mean age=31). The results are shown in (9) below.

(9) Percentage of strings identified as alternating: Duration *not* a stress correlate



The subjects were again able to correctly categorize the *no lapse* strings. However, we see a very different effect of strings having either type of edge syllable from what was previously found. This shows that although the stress cues in the strings were not what the subjects were used to from their native language, they were able to perceive them, and further, perceived the phonetic characteristics of the edge syllables differently in light of them.

Looking at the *final test* strings, we see that although there is a significant increase in "alternating" responses over *final lapse* strings ($p < 0.001$), the amount (17.6 percent) does not reach the confusability threshold, and, of course, is not a greater increase than is seen for *initial lapse* strings. Remember that the *final test* strings in fact alternate in vowel quality, since the phonetic characteristics of final syllables include full(er) vowels. So while we saw in (7) that vowel quality was needed to elicit the perception of rhythm, we see here that it is not sufficient to do so. If it is only the vowel quality that is important then we would expect the alternating vowel quality in the *final test* strings to have produced a higher number of "alternating" responses than we see in (9). The low number of "alternating" responses for the *final test* strings is in line with the database finding that very few languages that did not use duration in their realization of stress in fact tolerate final lapse, and is also consistent with the hypothesis that this is because of a true lapse in rhythm in those cases.

There is a strikingly high percentage of "alternating" responses to *initial lapse* and *initial test* strings. Initial lapses seem to be more difficult to perceive in non-duration-cued stress for English speakers. Further, and perhaps more interestingly, *initial test* strings have the kind of effect that we saw before with *final test* strings: they are identified as alternating significantly more often than *initial lapse* strings ($p < 0.001$), they are identified as being alternating at least 50 percent of the time (in fact, 64.9 percent), and the increase is greater than we find

between the strings with final stress lapse. The fact that *initial lapse* strings now seem to be behaving the way we previously saw *final test* strings behave makes sense, since the phonetic characteristics of initial strengthening now align with the cues to stress (higher pitch and intensity), which could then reasonably lead to the perception of a rhythmically alternating string. And in fact, stress in the language known to tolerate initial lapse, Winnebago, is realized through pitch and intensity (Miner 1979). It is worth nothing, however, that this study placed all edge cues on the vowels and used identical consonants in each syllable, while initial-strengthening actually affects the initial consonant more than the following vowel. It is therefore unclear whether initial-strengthening should be generally expected to be able to contribute to the rhythm in languages that cue stress with pitch and intensity.

4.4 Summary of experiment findings

Despite the entangled effects of duration and vowel quality for English speakers, we have seen that the phonetics of word-final unstressed syllables can contribute to the perception of a rhythmic alternation throughout the word, provided that stress is cued with duration. If stress is not cued with duration, the phonetic characteristics of a final syllable do not cause the perception of the rhythmic pattern being continued. The results from the perception experiments fall in line with the correlations found in the database between a language's use of duration in the realization of stress and its tolerance of final stress lapse.

5 Theoretical implications

We have seen evidence that the phonetic characteristics of word-final syllables can contribute to the perceptual rhythm of a word. Given this connection, we might wonder whether final lengthening has sometimes been perceived as stress by linguists in the field. In fact, the suggestion that this might be the case has been made by Hayes (1995: 100). Among languages that stress the initial syllable and every other thereafter, he found seven languages that do not exclude the final syllable compared with 12 that do exclude it. Those that do not would require, in his foot-based pre-OT account, a degenerate foot in odd-syllabled words, which his theory avoids. Hayes specifically proposes the possibility that phrase-final lengthening could be responsible for linguists mishearing final stress in the seven relevant languages that are documented as having final stress in odd-syllabled words. This suggestion is not consistent with the results found here, however. One of the languages in Hayes (1995) described as having the (σ́σ)(σ̀σ)(σ̀) pattern is Czech. Duběda and Votrubec (2005) found that stress is cued with pitch in Czech, and specifically not with duration. As the final experiment in the previous section demonstrated, final lengthening is unlikely to be heard as continuing the rhythmic pattern in non-duration-based-stress languages. Given the evidence explored here we might instead ask, if final lengthening contributes to the rhythm of a word, why languages that do use duration to cue stress have been heard and documented as having a final stress lapse. The assumption is that a stress lapse is distinguishable from what we might call a rhythmic lapse. The fact that syllable strings with unstressed final syllables with final lengthening were identified as alternating significantly less than strings where every other syllable was stressed suggests that there is a distinction. As final lengthening will be present

when the penult bears a stress as well as when it does not, linguists presumably factor out the final lengthening inherent in the final position when determining stress. While we clearly need more acoustic comparisons of phonetic final lengthening in stressed and unstressed syllables across languages, it seems reasonable to assume that the word-final-edge phonetics are never going to exactly match those of phonological stress. Presumably the two remain distinct, even in languages like English where we have seen confusability. There has been a call for more careful investigation of stress systems (e.g. de Lacy 2014, Gordon 2014) and certainly clarifying the status of final syllables should be among those points given attention.

A language's phonetic realization of primary and secondary stress can differ, and so a relevant question is whether duration must crucially be a cue to stress for both stress levels, or whether it must only be a cue to either primary or secondary stress. This question cannot be answered at the present time, as the perception studies only used one level of stress, and reported cues to primary and secondary stress levels are combined in the database (as not enough studies report them separately to allow for further subdivision). While we might expect that it is secondary stress which is crucial for setting up the rhythm of the word, other possibilities exist. Since words tend to be short, we might expect the majority of words to have only a single stressed syllable, and in those cases the cues to primary stress would be the only relevant ones. Further, it is unknown whether final lengthening would have the effect it did in Experiment 1a if the initial syllable were stressed with a phonetic realization that included duration but the subsequent stresses were not cued with duration. Since duration would be a cue to prominence in such languages, it is possible that final lengthening could still have a perceptual effect of prominence, even when the closest stress does not use duration. Thus, whether it is the phonetic cues to primary, secondary, or both stress levels that are relevant here is an open question.

Returning to the typology as it is currently understood, we now have a rationale for the relatively large number of languages that tolerate final stress lapse. We have seen that such languages are likely to use duration in their realization of stress, and that the phonetic characteristics of final lengthening in English can lead to the perception of continued rhythm. We would like to see the results of perception studies on speakers of other languages, including those, like English, which tolerate a final stress lapse, have a stress-based duration difference, and have word-edge phonetic characteristics which create the perception of a continued rhythmic pattern. We would expect to find the same perceptual effect with the *final test* strings as was found for English speakers.

If final stress lapse is tolerated in many languages because it does not interrupt the rhythm of the word, this allows us to reframe the typology. One option to implement the theory that two adjacent unstressed syllables can still be perceived as continuing the rhythm of the word in language in which duration is cued by stress (and which has final lengthening) would be to redefine the requirement against stress lapse (instantiated in OT through the constraint *Lapse) as a phonetic-based *Prominence-Lapse that would not penalize two adjacent unstressed syllables as long as they exhibited a rhythmic alternation (either through stress or through phonetic prominence). Such a constraint would be violated by two adjacent unstressed syllables at the end of the word in some languages and not in others, depending on whether final syllables under a stress lapse were perceived as alternating in prominence. In a language like English, we have reason to think that a final stress lapse does not interrupt the rhythm of the word, and, therefore, that a word like *a.spá.ra.gus* would not run afoul

of a phonetic-based no-lapse requirement. On the other hand, a word-final stress lapse in a language like Czech would violate such a requirement, since stress is realized through pitch, and not duration.

The current proposal changes the approach from the viewpoint of extrametricality/nonfinality, which sets aside the final syllable, to one where, in many cases, the final syllable does not need to be stressed to maintain the rhythm and therefore there is no reason to do so. This is compatible with the OT approach to stress systems which treat stressed syllables or feet as marked, meaning that having more of them is penalized (through ALIGNMENT constraints that pull all stresses/feet as close to a word-edge as is tolerated given higher-ranked constraints). Under the typical OT approach to stress, a stress (or foot with a head) exists in order to satisfy a higher-ranked markedness constraint like *LAPSE. But given the constraint *PROMINENCE-LAPSE, there would be no motivation to stress the final syllable in a language with duration-cued stress and final lengthening. Given that the stress correlates database includes languages like the Uralic language Enets (Künnap 1999) which do stress the final syllable in odd-syllabled words, despite using duration as a cue to stress, it seems we need both the traditional *LAPSE constraint and the proposed *PROMINENCE-LAPSE in the constraint set. (Another possibility is that such languages do not tolerate a final stress lapse because final lengthening is suppressed.) Examples of how *PROMINENCE-LAPSE can work is shown in the tableaux below, assuming systems of primary stress on the initial syllable and secondary stress every other syllable thereafter, excluding the final syllable (in (10)) or including the final syllable (in (11)). (The stress alignment constraints are shown evaluated gradiently, but result is the same if they are evaluated categorically.)

(10) Language with duration-cued stress

	/σσσσσ/	*PROM-LAPSE	*CLASH	ALL-STRESS LEFT	*LAPSE
	a. σ́σσ̀σσ̀			6!	
☞	b. σ́σσ̀σσ			2	*
	c. σσ́σσ̀σ			4!	

In a language with duration-cued stress, if *PROMINENCE-LAPSE is ranked higher than *LAPSE, then a final stress lapse will be tolerated in an odd-syllabled string like (10b). Either a third stress (candidate (a)) or non-edge stresses (candidate (c)) will incur an unnecessary number of alignment violations (here, of stresses, but could of course be of feet). In a language without duration-cued stress, however, *PROMINENCE-LAPSE will work exactly like *LAPSE, as shown below.

(11) Language without duration-cued stress

	/σσσσσ/	Primary Stress-Left	*Prom-Lapse	*Clash	All-Stress Left
☞	a. σ́σσ̀σσ̀				6
	b. σ́σσ̀σσ		∗!		2
	c. σσ́σσ̀σ	∗!			4

In (11), we see that candidate (b) incurs a fatal violation of *Prominence-Lapse, since of course any final lengthening in the final syllable will not contribute to continuing the rhythm of the word as stress is not cued through duration. Speakers presumably learn through experience whether there is an alternation in prominence over two unstressed syllables in their language or not, which is reflected in the differing evaluation of *Prominence-Lapse.

Notice, however, that nonfinality cannot be removed from the constraint set. We still find it active in a language like Hixkaryana which is analyzed as footing iambs from the left with nonfinality (Kager 1999), e.g. *a.tʃó.wo.wo* 'wind'. Such systems are difficult to analyze in foot-less systems, and in fact "every even syllable from the left excepting the final syllable" is a pattern predicted not to exist in the system of Gordon (2002).[14] But if we assume that the final stress lapse nevertheless carries an alternation in rhythm (and that stress is realized through duration) then a foot-less OT analysis is possible.[15]

6 Conclusion

This chapter has explored the relationship between the word-edge phonetic effects on final syllables and languages' stress patterns, uncovering a relationship between the tolerance of word-final stress lapse and the use of duration as a stress correlate. Evidence that there is a connection has come from demonstrating that a correlation exists between languages that tolerate a final stress lapse and those that use duration as a cue to stress. A one-way implication was found to hold: while languages that use duration as a cue to stress are no more or less likely tolerate final stress lapse, almost all languages that tolerate a final stress use duration as a cue to stress. Assuming the presence of word-level final lengthening, it is the case that two unstressed syllables at the right edge of the word will still alternate in duration, and, when duration is a cue to stress, it is consistent to think that this non-stressed-based prominence contributes to the rhythm of the word. Support for this perceptual argument comes from the experiments discussed in Section 4, where strings of syllables that set up a stress-based rhythmic alternation but end in word-final lapse, with the final syllable bearing the characteristics of a word-final syllable (longer, and having a fuller vowel quality than

[14]This is because the effect of iambs is achieved by aligning stresses to the right edge. NonFinality can keep stress from falling on the final syllable but not from falling on the penultimate syllable. In a six-syllable word (of all underlyingly light syllables) canonical *Lapse will force there to be three stressed syllables, not the actual two the pattern produces: σσ́σσ́σσ. Since Hixkaryana is a quantity-sensitive system it is not officially within the purview of Gordon's typology.

[15]The Hixkaryana pattern is predicted by van der Hulst's rhythmic parameters, as the "free beat addition" component of the rhythm parameter will always (when active) add a beat to avoid an initial lapse, but can be prevented from doing so to avoid a final lapse by the NonFinality parameter.

non-final unstressed syllables), were found to be confusable with syllable strings that had a stress-based rhythmic alternation throughout.

If the proposed connection between final lapse and the use of duration is correct, this is a case where a phonetic presence (of duration) from completely different sources (phonological stress, word-edge phonetics) can both play a role in the perception of a phonological phenomenon (rhythm). It also raises the possibility that more such connections could be found, especially as our knowledge (and certainty level) of languages' stress correlates improves.

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