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Weight effects and the role of the foot: English versus Portuguese

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This article explores the possibility that even though English and Portuguese present similar stress patterns on the surface, the two languages may be formally different: whereas English offers strong evidence for the foot, Portuguese does not. We present new data on the relationship between syllable weight and antepenultimate stress in both languages. We experimentally show that weight effects in English are consistent with an analysis of stress that employs feet. Weight effects in Portuguese, in contrast, are not optimally accounted for by a foot-based analysis. Sonority effects captured in our experimental data from Portuguese further question the role that the foot plays in this language, but not in English. Additional evidence for the foot in English comes from word minimality constraints, which are never violated in the language, unlike in Portuguese, where violations are commonly observed both in the lexicon and in derived words.

1. Introduction

Prosodic phonology assumes that syllables are organized into feet, the domain where word-level prominence is realized (Nespor & Vogel, 2007; Selkirk, 1984). One of the central motivations for feet cross-linguistically is the observation that languages systematically constrain the window of syllables in which stress can fall;[1] indeed, in the vast majority of languages, stress is located within a trisyllabic window at the left or right edge of the word—a bisyllabic foot with one additional syllable at an edge (see Gordon (2016) and Kager (2012) for comprehensive reviews). Besides delimiting the domain of stress, feet also express *where* within this domain stress is expected to fall.

Although stress is not a property of all languages, the foot has nevertheless been proposed to be universal (e.g., Inkelas & Zec, 1995; Nespor & Vogel, 2007; Selkirk, 1996; Vogel, 2010; see also Crowhurst, 2020). This position has been challenged by some researchers for languages from different families, including French, Turkish and Vietnamese, where prominence assignment does not have the typical signatures of word-level stress (e.g., Jun & Fougeron, 2000; Özçelik, 2014; Schiering et al., 2010).

In the present paper, we question the status of the foot from the perspective of Brazilian Portuguese (henceforth *Portuguese*). On the face of it, Portuguese has a very similar stress system to English, a language for which the presence of the foot has not been challenged: in both languages, regular stress in non-verbs (nouns and adjectives) seemingly can be captured by binary left-headed weight-sensitive feet (i.e., moraic trochees). In Portuguese, stress falls on the final syllable if that syllable is heavy (e.g., *jor(nál)* 'newspaper') and on the penultimate syllable otherwise (e.g., *sa(páto)* 'shoe') (see, e.g., Bisol, 1992).[2] In English, stress falls on the penultimate syllable if that syllable is heavy (e.g., a(gén)⟨da⟩) and on the antepenultimate syllable otherwise (e.g., (Cána)⟨da⟩). The principal difference between these two systems seems to be extrametricality, given that the final syllable is visible for footing in Portuguese, but is not in English (e.g., Hayes, 1982).

Even though the stress systems of Portuguese and English look similar on the surface, we will show that they are different with regard to weight and possibly footing. This cross-language difference is not unexpected given earlier literature: unlike in English, where evidence that moraic trochees regulate stress is robust (e.g., Hayes, 1995), weight effects in Portuguese are not consistent with any foot type, and thus pose a major challenge for traditional foot-based approaches to stress (Garcia, 2017a). Our main goal in this paper is to experimentally probe for weight effects in antepenultimate position in both Portuguese and English. We find that a

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1 In this paper, *stress* is to be equated with *main stress*.

2 Portuguese words are not phonetically transcribed in this paper as weight information is predictable from the orthography: all vowels are short, and coda consonants, which are moraic, are realized either as C or as V due to lenition. Further details on the phonetic quality of codas are provided in Section 3.

positive weight effect is observed in this position in Portuguese (following Garcia, 2019), which we will see is surprising if the language optimizes moraic trochaic footing. We do not find a positive weight effect in antepenultimate position in English. Although the absence of such an effect is as predicted if English rigorously builds moraic trochees, this has not, to our knowledge, been experimentally examined. Our second goal is to show that the weight effects observed for each language are supported by word minimality. In Portuguese, we commonly find existing words that violate word minimality, that is, words that are monomoraic and, therefore, smaller than a (binary moraic) foot. Subminimal words are also found in productive phenomena such as hypocorization. In English, however, existing words are at least one binary foot in length—the same is true of productive phenomena such as truncation and hypocorization, which never yield monomoraic outputs. In other words, English never violates word minimality, which is indirectly imposed by the prosodic hierarchy and the foot binarity condition (e.g., McCarthy & Prince, 1995). Taken together, we conclude that several prosodically conditioned constructions in Portuguese and English suggest that distinct formal systems may regulate lexical stress in these languages, despite the fact that they have similar rhythmic patterns on the surface.

The paper is organized as follows. First, we review stress and footing in Portuguese and English (Section 2). Second, we present and statistically model experimental results on Portuguese and English stress (Sections 3–4); we show that the results for antepenultimate position motivate footing in English, but question this for Portuguese. Third, in Section 5, we demonstrate that our experimental results are consistent with differences in the truncation and hypocorization patterns in Portuguese versus English. Finally, in Section 6, we discuss the implications of our results for the status of the foot in prosodic phonology.

2. Stress and footing

2.1. Portuguese

Primary stress in Portuguese is constrained by a trisyllabic window, as mentioned above: *marítimo* 'maritime', *martélo* 'hammer', *papél* 'paper'; pre-antepenultimate stress is illicit in the language: **máritimo*. Even though both verbs and non-verbs respect this trisyllabic window, stress in these two classes of words is driven by different factors: stress in verbs is heavily influenced by morphological factors (see Wetzels (2007) for a review), while stress in non-verbs relies mostly on phonological factors like weight (Bisol, 1992; Garcia, 2017b; Lee, 2007; Wetzels, 2007). In this paper, we focus on stress in non-verbs, which is typically assigned as per Rule (1)—H stands for a heavy syllable, L for a light syllable, and X for any syllable (H or L).

(1) **Portuguese stress in non-verbs**

Final stress if the final syllable is heavy:	*papél* 'paper', *rapáz* 'boy'
Else, penultimate stress:	*martélo* 'hammer', *varánda* 'veranda'

Traditionally, all stress patterns that deviate from (1) are considered to be irregular. These include all words in the Houaiss Dictionary (Houaiss, Villar, and de Mello Franco, 2001) with antepenultimate stress (13% of non-verbs; Garcia (2014)), regardless of the weight profile involved (H́LL: *fósforo* 'match' (noun), ĹHL: *pénalti* 'penalty', ĹLH: *júpiter* 'Jupiter'). Irregular cases also include words with penultimate stress that have a heavy final syllable (XX́H; *esténcil* 'stencil', *nível* 'level'; 11% of non-verbs), and words with final stress that have a light final syllable (XXĹ: *jacaré* 'alligator', *tatú* 'armadillo'; 3% of non-verbs). Approximately 72% of the Portuguese lexicon can be accounted for by the algorithm in (1) (Garcia, 2017b), which makes it relatively robust. In spite of this, researchers do not agree on what type of feet Portuguese builds, as well as what extra machinery must be employed to account for the various irregular patterns found in the language.

Bisol (1992) proposes that regular stress in Portuguese requires both moraic and syllabic trochees: moraic trochees capture XXH́ words, which contain a heavy final syllable and bear final stress; syllabic trochees capture XX́L words, which contain a light final syllable and bear penultimate stress. Bisol also assumes that both syllabic and moraic trochees are employed in irregular patterns. She proposes that the final syllable in words with antepenultimate stress is exceptionally marked as extrametrical.[3] As a result, these words have the same foot structure as regular penultimate stress (i.e., they involve syllabic trochees).

Bisol's approach does not straightforwardly extend to cases of word-final stress on light syllables. To capture this pattern, some scholars assume that Portuguese builds both trochees and iambs (Bonilha, 2004; Lee, 2007). Bonilha (2004), for example, proposes that iambs are built in words such as *abacaxí* 'pineapple' and *urubú* 'vulture' due to the word-final vowels in question (/i, u/): underlyingly high vowels in word-final open syllables virtually always attract stress. According to Bonilha, /i, u/, "when positioned at the end of the prosodic word, are considered good peak elements" (p. 41). This assumption, however, is inconsistent with the fact that, among vowels, high vowels have the lowest sonority (de Lacy, 2006; Ladefoged & Johnson, 2011). Indeed, in Portuguese, /e, o/ in final unstressed syllables are lenited to [i, u], respectively, consistent with the low sonority of the latter. If final stress on light syllables were truly driven by sonority, then XXL words ending in /a/ would be the best candidates for final stress—but this is not the case.

Lee (2007) also assumes that both iambic and trochaic feet play a role in the grammar of Portuguese. Lee proposes an optimality-theoretic account and, thus, takes advantage of the position that constraints that strive for outputs conforming to both foot types will be present in every grammar: FtForm = Iamb and FtForm = Trochee. Iambic feet are built in XLĹ words such as *jacaré* 'alligator': ja(caré), and trochaic feet are built in XĹL words such as *caválo* 'horse':

[3] Wetzels (2007), instead, proposes dactyls for words of this shape.

ca(válo). Note that, under this approach, having two foot types active in a single language results in indeterminacy. For example, a XLH́ word could be parsed with a final moraic trochee (i.e., XL(H́)) or bisyllabic iamb (i.e., X(LH́)).

Some analyses of Portuguese assume that theme vowels play a role in stress assignment (e.g., Lee, 2007; Pereira, 1999, 2007). Theme vowels are always unstressed, and consist of {e, a, o} in Portuguese—in a word such as *gát-o* 'cat', the theme vowel (*-o*) indicates gender (masculine). In these analyses, stress is assumed to fall on the last vowel of the stem: *gát]-o*, *jornál]* 'newspaper', *café]* 'coffee'. As a result, feet are not necessary to account for regular stress patterns: if theme vowels are never stressed, then the final vowel in words like *café* cannot be thematic, and must instead be part of the stem. A significant challenge for this approach is that we only know if a given vowel is thematic if it is not stressed. As the following pairs of words show, {e, a, o} can be thematic or not, depending on where stress falls: *cón-e* 'cone' versus *café* 'coffee'; *cóbr-a* 'snake' versus *sofá* 'sofa'; *gát-o* 'cat' versus *robó* 'robot' (see critique in Garcia 2017b). In addition, no mechanism (e.g., extrametricality) is available to capture words with antepenultimate stress, which predicts that no generalizations hold for words of this shape. However, Garcia's (2017b) examination of the Portuguese lexicon suggests otherwise: antepenultimate stress is statistically more likely to occur in LLL words than in HLL words.[4]

This observation follows if Portuguese prioritizes the building of moraic trochees and if final syllables are extrametrical in words with antepenultimate stress (e.g., Bisol, 1992). On this view, ĹLL should be preferred to H́LL because in the latter word shape, both possible parses are non-optimal: the medial syllable could be left unparsed, as in (2a), but this results in a cross-linguistically marked metrical configuration; alternatively, an uneven trochee could be built, as in (2b), but this yields a typologically disfavored foot type (Hayes, 1985; Prince, 1990). In contrast, ĹLL words face neither of these problems, as shown in (2c), which could thus explain why words of this shape are more frequent than H́LL words in the Portuguese lexicon.

There are, of course, rankings that can generate (2a) or (2b) as optimal relative to (2c) if other metrical constraints are factored in, notably Stress-to-Weight (stressed syllables are heavy). In Chimalapa Zoque, stressed syllables undergo trochaic lengthening yielding (H́L) from (ĹL) (Hyde, 2011), indicating that Stress-to-Weight is dominant. Uneven trochees are also optimal in tone languages like Mandarin, where duration is the main correlate of stress because pitch is earmarked for lexical contrasts (Qu, 2013). However, in most trochaic languages, as Portuguese is described here, Stress-to-Weight does not play a determining role, in contrast to the role that it typically plays in iambic languages.

4 We emphasize the lexicon here as we will see in Section 4.1 that the experimental results from speakers of Portuguese do not reflect the lexicon as concerns preferences for antepenultimate stress in LLL versus HLL words.

(2) **Antepenultimate weight effects**

ĹLL ≻ H́LL due to metrical optimization:

a. (H́)L⟨L⟩ → Unparsed syllable

b. (H́L)⟨L⟩ → Uneven trochee

c. (ĹL)⟨L⟩

Moraic trochees have been posited to regulate other patterns in Portuguese as well. Nevins (2012), for example, proposes this for patterns of vowel lenition. In a word such as *moléque* /molɛ́ke/ 'boy', lenition occurs post-tonically ([molɛ́ki]) or both pre- and post-tonically ([mulɛ́ki]), but not just pre-tonically (*[mulɛ́ke]). Nevins explains the asymmetry in question with foot structure: the post-tonic syllable is in the weak position of a trochee, whereas the pre-tonic syllable is unfooted. Obligatory post-tonic vowel lenition would therefore serve the purpose of augmenting the contrast between the strong and weak positions of a foot. Unfortunately, all of the words considered in Nevins's study are trisyllables with penultimate stress. Crucially, Portuguese lenites vowels word-finally, regardless of whether stress falls on the penult (with the final syllable in foot-dependent position) or on the antepenult (with the final syllable outside the foot). Thus, we can conclude that, instead of lenition being regulated by foot structure, it occurs because the affected syllable is word-final, a position often associated with weakening across languages (see, e.g., Gordon, 2016). No conclusion regarding the status of the foot in Portuguese can therefore be drawn from the pattern in question.

Returning to stress, we have seen that proposals for Portuguese differ in how much emphasis is placed on the foot and on the type or types of feet that the language employs. Stem-based approaches assume that the foot plays, at best, a minor role. In other approaches, the foot plays a definitive role, but no general consensus about foot type emerges across proposals. Indeed, a particularly worrisome finding is that more than one foot type has been proposed to be simultaneously active in the language, either different types of trochees (Bisol, 1992; Wetzels, 2007), or different types of feet, i.e., trochees and iambs (Bonilha, 2004; Lee, 2007; Wetzels, 1992). Although the preference for ĹLL over H́LL observed in the lexicon may appear to support moraic trochees over other foot types, as mentioned, we will see that this finding is not mirrored in experimentally collected data. The lack of consistency within and across proposals stems from conflicting patterns in the language, which are more intricate than what has traditionally been assumed. We return to the question of footing in Portuguese in Section 5.1. We first examine stress in English non-verbs.

2.2. English

As already mentioned, the stress systems of Portuguese and English are, on the face of it, very similar. Unlike for Portuguese, however, there has not been much debate as to which metrical structures best characterize the English system (see Chomsky & Halle, 1968; Halle & Idsardi, 1995; Halle & Vergnaud, 1987b; Hayes, 1982; Liberman & Prince, 1977; Selkirk, 1980 among others). In English non-verbs, stress falls on the penultimate syllable if that syllable is heavy, and on the antepenultimate syllable otherwise, as can be seen in (3b) and (3c). The examples in (3b) show that heavy penultimate syllables contain a coda consonant (*veránda*) or a long vowel (*oppónent*). Final stress in nouns and adjectives tends to be avoided (Giegerich, 2005, p. 185), but can be found in words ending in VV(C) syllables (Halle & Vergnaud, 1987a); see (3a).[5]

(3) **English stress in non-verbs**

a.	Final stress in VV(C)]$_\omega$ words	*canóe, políce*
b.	Penultimate stress if the penultimate syllable is heavy: XH́X	*veránda, oppónent*
c.	Antepenultimate stress otherwise: X́LX	*Cánada, ártifice*

Given the behavior of word-final syllables shown in (3b) and (3c), extrametricality has played a central role in metrical accounts of English stress. Hayes (1982), for example, proposes that the final syllable in nouns is extrametrical, and is therefore invisible during stress assignment: ve(rán)〈da〉. For words with final stress, such as those in (3a), Hayes proposes a rule (Long Vowel Stressing) that assigns a foot to such syllables. We can thus summarize the stress algorithm in English non-verbs as follows: starting at the right edge of the word, stress is final if this syllable contains a VV(C) rhyme. Else, the penultimate syllable is checked. If a heavy syllable is found, stress is penultimate. Else, stress is antepenultimate. This algorithm can account for over 80% of the words in a subset of the Carnegie Mellon University Pronouncing Dictionary (Weide, 1993) containing 6,531 nouns and adjectives (excluding disyllables). Although this might not seem substantially higher than the 72% observed earlier for Portuguese (Section 2.1), unlike in Portuguese, the vast majority of exceptions in English involve words where extrametricality exceptionally does not hold (e.g., va(nílla)).

Because English is a weight-sensitive language, and because final stress is typically avoided in non-verbs, the foot type standardly assumed for the language is the moraic trochee. Indeed, processes such as Trochaic Shortening (e.g., Hayes 1995) support an analysis based on moraic trochees: the long vowel in roots like *sane* [seɪn] is shortened when the suffix *-ity* is attached, enabling an optimal parse of the resulting string, namely (2c) above: [(sǽnɪ)〈ti〉]. This highlights an important difference between English and Portuguese: there is wide agreement in the literature that moraic trochees, and not syllabic trochees (or iambs), capture stress in the former language but not in the latter.

[5] Final stress can also be found in words with final short vowels in borrowings from French, which tend to be faithful to the source language's final stress pattern (e.g., *hotél*).

2.3. Summary

In sum, we have established that English supports (a particular type of) footing, while the evidence from Portuguese is less clear. Although weight effects are robustly observed in both languages, a question that must be addressed is whether weight effects, in and of themselves, motivate footing and whether the same conclusion can be reached for both languages on this matter.

Both languages show that heavy syllables (of particular profiles) attract stress in final and penultimate positions. Concerning antepenultimate position, we saw earlier (in (2c)) that if weight regulates footing, there should be a preference for light syllables in this position. Seemingly consistent with this, a preference for ĹLL over H́LL is observed in the Portuguese lexicon (Garcia, 2017b). Trochaic Shortening in English similarly favors ĹLL over H́LL. Although such patterns may appear to provide solid support for moraic trochees in both languages, Garcia (2019) shows that the frequency effect in the Portuguese lexicon is not upheld in the judgments of native speakers. In light of this finding, it is essential that we test the judgments of English speakers as well to verify whether the lexical patterns in English are reflected in speakers' grammars.

In the next sections, we experimentally examine whether weight effects in antepenultimate position are observed for native speakers of English as well as Portuguese, and if so, what profile they take. Evidence that footing is sensitive to weight would come either from a negative weight effect in antepenultimate position, where stressed light syllables are preferred over stressed heavy syllables (ĹLL ≻ H́LL), as seen earlier in (2c), or from a null weight effect in said position (ĹLL = H́LL). In contrast, a positive weight effect in antepenultimate position, where speakers generalize the effects of weight from penultimate and final positions and thereby prefer stressed heavy syllables over stressed light syllables (H́LL ≻ ĹLL), would challenge the role of the foot in regulating stress; this is because the parse for H́LL would either involve a medial unfooted syllable or an uneven trochee, as seen earlier in (2a) and (2b), respectively. Indeed, WEIGHT-TO-STRESS (heavy syllables are stressed), a constraint that does not require footing, could capture positive weight effects in all positions in the stress window.

3. Method

3.1. Task

In our study, we employ two forced-choice judgment tasks, developed in Praat (Boersma & Weenink, 2024), one for Portuguese and one for English. Participants in both experiments were auditorily presented with minimal pairs differing in stress location and were asked to choose which of the two pronunciations sounded more natural ('Portuguese-like' or 'English-like'). They were explicitly told that all of the words were invented and represented objects, not actions or qualities. The stimuli were pseudo-randomized, as was the order in which different stress patterns were presented within pairs. Participants were also asked to rate their level of certainty on a 6-point scale. Finally, participants' reaction times for each response were recorded.

3.2. Stimuli

All stimuli for the Portuguese experiment were generated using a script (now part of the `Fonology` package (Garcia, 2023)) in R (R Core Team, 2024). Stimuli for the English experiment were also generated in R, using regular expressions over a set of target phonemes. The stimuli for both languages were then manually checked for phonotactic naturalness by native speakers of each language. Attested but uncommon sequences were removed.

For the Portuguese experiment, the design and stimuli (n = 240) replicated Garcia (2019), which is, to our knowledge, the only experimental study examining weight effects in antepenultimate syllables in Portuguese. Four weight profiles were included: LLL, HLL, LHL and LLH. LLH, however, will not be discussed; this is because words of this shape were not included in the English experiment, as final heavy syllables do not regularly attract stress in this language (see Section 2.2). Heavy syllables were of the shape vowel + /s N l r/. In standard Brazilian Portuguese, these segments are produced as follows: coda N is realized as a homorganic nasal in medial position and as nasalization on the preceding vowel with or without a nasal murmur in final position. Coda /l/ is always vocalized to [w]. Coda /s/ and /r/ are realized variably but were always produced as [s] and [ɾ] in our stimuli. Representative examples are provided in **Table 1**.

LLL	HLL	LHL	LLH
ga.no.mo	tɾiŋ.ga.bo	pa.diɾ.to	tu.bɾa.dal
gɾa.ko.lo	tɾus.ko.me	mu.plos.te	ʒa.ko.maɾ
di.ɾa.na	ʒes.pɾi.la	za.gɾen.te	po.ɾe.bɾos

Table 1: Sample stimuli used in the Portuguese experiment.

For the English experiment, stimuli (n = 180) were selected based on the same conditions used in the Portuguese version of the experiment, namely, weight profile and coda type. Three weight profiles were used: LLL, HLL and LHL. In HLL and LHL words, heavy syllables always contained a coda, rather than a long vowel, to optimize comparison with Portuguese, which lacks long vowels. The coda in the heavy syllable was either a voiceless obstruent (/p t k f s/) or a sonorant (/m n ŋ l r/). All final syllables were of the shape [CəC], a common profile for final light syllables in English. Antepenultimate and penultimate vowels were drawn from the set /ɪ ɛ ɑ/; vowels were not reduced to schwa when unstressed (spectrally verified in Praat (Boersma

& Weenink, 2024)), to ensure that the stimuli being compared only differed in stress location. Representative examples are provided in **Table 2**.

LLL	HLL	LHL
pɹɪ.tɑ.ɹək	nɑɹ.pɛ.lət	kɛ.pɹɑn.təs
lɑ.pɹɛ.sən	pɹɛn.dɪ.nəf	pɛ.tɹɑŋ.kəp
sɑ.pɪ.nəɹ	kɹɪm.pɛ.dən	dɛ.lɪs.pən

Table 2: Sample stimuli used in the English experiment.

The Portuguese stimuli were produced by a female native speaker of standard Brazilian Portuguese, and the English stimuli by a male native speaker of standard Canadian English. Both speakers had extensive training in phonetics and prior recording experience. The Portuguese stimuli were provided to the speaker in orthography. The English stimuli were provided in phonetic transcription, given that the orthography is ambiguous as concerns both vowel quality and length (cf. the experiments undertaken by Domahs et al., 2014 and Guion et al., 2003). Each nonce word of the shape LLL, HLL and LHL was recorded with both antepenultimate and penultimate stress, which resulted in minimal pairs that differed only in the location of stress.

3.3. Participants

For the Portuguese experiment, participants were native speakers of Brazilian Portuguese (n = 26; 17 females). For the English experiment, participants were native speakers of North American varieties of English (n = 25; 21 females). Both groups were living in Montreal at the time of testing. Most of them spoke other languages (especially French) at different proficiency levels, but none of them was bilingual from birth. Participants in the Portuguese experiment ranged from 22 to 43 years of age, and all had completed post-secondary education. Participants in the English experiment ranged from 19 to 29 years of age, and all were currently enrolled in or had completed post-secondary education.

3.4. Predictions

Before discussing our predictions, we review the definition of each possible effect of weight. A positive weight effect indicates that heavy syllables are more likely to attract stress. In contrast, a negative effect of weight yields the opposite pattern, whereby heavy syllables repel stress. Finally, a null effect indicates that heavy and light syllables are statistically equally good at attracting stress (i.e., no difference between them can be detected).

For the Portuguese experiment, we predict a positive effect of weight in both penultimate and antepenultimate positions, the same effect found in Garcia (2019). For the English experiment, we predict that the English grammar will influence well-formedness judgments as follows: speakers' behavior will be regulated by moraic trochees, such that a positive weight effect will be observed in penultimate position, but a non-positive (i.e., negative or null) effect will be observed in antepenultimate position. More concretely, in penultimate position, we predict that speakers will prefer LH́L to LĹL, given that the grammar of English favors the parse L(H́)⟨L⟩ over L(ĹL), which has a well-formed foot but no extrametricality, and over L(Ĺ)⟨L⟩, which contains a subminimal foot to respect extrametricality. In and of itself, a preference for LH́L does not motivate foot structure, as the same effect could be captured with WEIGHT-TO-STRESS relativized to different positions in the stress domain (see Section 6). Coupled with the absence of a positive weight effect in antepenultimate position, however, a role for foot structure emerges: we predict that speakers will not prefer H́LL to ĹLL, given that a positive weight effect in antepenultimate position would lead to marked parsings (shown earlier in (2a)–(2b)).

4. Results and analysis

4.1. Portuguese results

Figure 1 presents the main results from the Portuguese experiment. Overall, we can see that the preference for antepenultimate stress is below 50% (*y*-axis) for all three weight profiles. This isn't surprising—recall from Section 2.1 that antepenultimate stress is a minor pattern in the language. Crucially, though, antepenultimate stress is preferred more often in HLL words (H́LL vs. HĹL) than in LLL words (ĹLL vs. LĹL). This suggests a positive weight effect in antepenultimate syllables, which we model below. Finally, LHL words have the lowest rate of preference for antepenultimate stress, which is what we would expect considering that ĹHL words are extremely rare in the language.

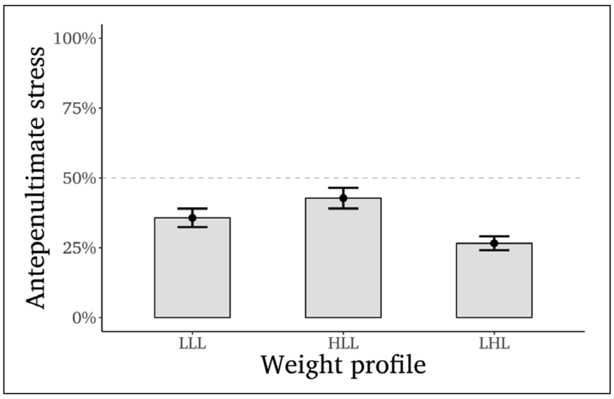

Figure 1: Overall weight effects on Portuguese stress: Percentages of preference for antepenultimate stress as a function of weight profile.

To statistically model the data shown in **Figure 1**, a Bayesian hierarchical logistic regression was run that included weight profile as a main effect and as a random effect in the form of by-participant random slopes. LLL was used as the reference level for weight, and is represented by the intercept of the model. Accordingly, we interpret the effect size of HLL and LHL in relation to LLL (our baseline). The model also includes by-word random intercepts—we used the default priors provided in the brms package (Bürkner, 2021), which means that no bias regarding the relationship between weight and stress preference is included in the model. Both effective sample sizes (ESS) and $\hat{R}$ were checked to confirm convergence of the four chains used in the model. The model was run using Stan (Carpenter et al., 2017) through the brms package in R.

The model estimates are shown in **Figure 2**, which also displays the region of practical equivalence (ROPE) for the parameters in question—LLL*, with an asterisk, represents the intercept. Simply put, if the entire posterior distribution is found within said region, we can statistically conclude that the effect is null (see, e.g., Kruschke, 2015)—this is clearly not the case here. Unlike frequentist approaches, which provide a single parameter estimate and the probability of the data given such an estimate, Bayesian approaches provide an entire distribution of credible parameter values. Thus, even though the mean $\hat{\beta}$s discussed below are the most probable parameter values,[6] the actual effects of interest are represented by entire distributions of parameter values.

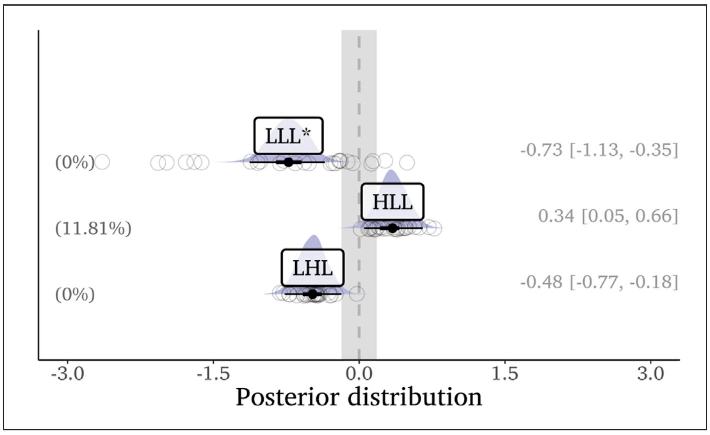

Figure 2: Parameter estimates and associated posterior distributions for Portuguese. The intercept is indicated with an asterisk. Credible intervals are shown in the figure and detailed on the right (mean [95% highest density interval, or HDI]). The percentage of each HDI that is contained within the ROPE (shaded area around 0.0) is shown on the left.

[6] Technically, the most probable parameter value would be the mode of the distribution. However, because the posterior distributions in question approximate a Gaussian distribution, the mean and the mode have very similar values.

In **Figure 2**, we see that the 95% highest density interval (HDI) of the posterior distribution for HLL is entirely positive (i.e., it doesn't include zero as a credible parameter value). The effect in question must be interpreted relative to the intercept (LLL), whose posterior distribution is entirely negative, confirming that antepenultimate stress is disfavored (compared to penultimate stress) in LLL words, consistent with **Figure 1**. The mean effect size in the posterior distribution for HLL is $\hat{\beta} = 0.34$ (shown to the right of the distribution in **Figure 2** along with the 95% HDI). We therefore conclude that, relative to the reference level, HLL words display a statistically higher level of preference for antepenultimate stress (vs. penultimate stress), thus confirming a positive weight effect in antepenultimate position. **Table 3** presents the same results along with $\hat{R}$ and ESS values.[7] $\hat{R}$ is used to inspect the convergence of the model (an $\hat{R}$ of 1 indicates the model has converged). ESS (n_{eff}) refers to the number of sampling steps assuming an uncorrelated chain.

The positive effect of weight observed in the results confirms the earlier findings of Garcia (2019). In his study, Garcia found effect sizes of $\hat{\beta} = 0.26$ and $\hat{\beta} = 0.16$ in his two experiments for HLL (the second experiment being a replication of the first). Thus, we not only replicate the results for HLL, but also capture a stronger effect size ($\hat{\beta} = 0.34$)—note that all three effect sizes come from the same experimental design and from the same stimuli. It is thus safe to conclude that the empirical evidence for weight effects in antepenultimate syllables in Portuguese is robust. We refer the reader to Kobrock & Roettger (2022) for important discussion on the scarcity of replication studies in experimental linguistics.

Table 3: Portuguese model. Mean parameter estimates and associated estimated errors, credible intervals, R̂, and ESS (n_{eff}).

Parameter	**Mean $\hat{\beta}$**	**Est Error**	**2.5%**	**97.5%**	**R̂**	**n_{eff}**
Intercept (LLL)	−0.73	0.20	−1.11	−0.34	1.0	1515
HLL	0.34	0.15	0.04	0.64	1.0	2594
LHL	–0.48	0.15	–0.77	–0.18	1.0	3014
MODEL: `stress ~ weight + (1+weight|participant) + (1|word)`						

We consider finally certainty levels and reaction times. Certainty levels did not show any particular trends for antepenultimate stress preference in HLL versus LLL words in our data. There were, though, two trends that were observed overall: first, participants were more certain

[7] Note that, unlike **Figure 2**, **Table 3** shows 95% credible intervals based on quantiles, not HDIs (Bürkner, 2017, p. 11). However, because the posterior distributions in question are approximately Gaussian, these intervals are practically equivalent to the HDIs shown in the figure.

about penultimate stress regardless of weight profile, a finding that is not surprising given the high frequency of penultimate stress in the language. Second, participants were least certain when choosing antepenultimate stress in LHL words, which is again consistent with frequency effects, given the extremely low frequency of ĹHL words in the language. Reaction times similarly revealed no trends related to the crucial question examined. However, we observed faster reaction times overall when participants chose penultimate stress and, once again, ĹHL words can be singled out as they displayed the slowest reaction times in the data. We do not discuss these two variables further.[8]

4.2. English results

We turn now to the English experiment. We start by analyzing the main variable of interest, namely, weight. In **Figure 3**, we can see the mean percentage of preference for antepenultimate stress across LLL, HLL and LHL words. Standard errors from the mean are also provided. Preference for antepenultimate stress is above 50% for LLL and HLL words, but below 50% for LHL words.

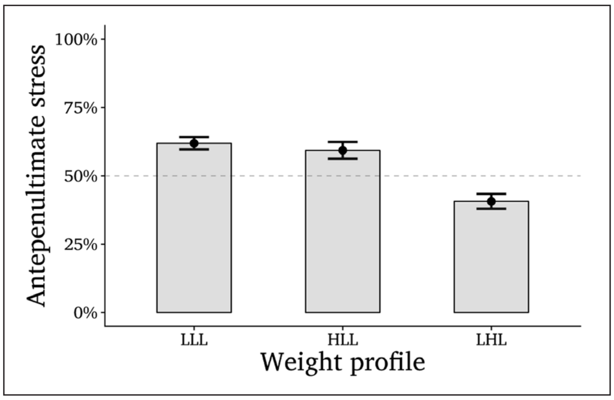

Figure 3: Overall weight effects on English stress: Percentages of preference for antepenultimate stress as a function of weight profile.

As with the Portuguese data discussed earlier, to statistically model the data shown in **Figure 3**, a Bayesian hierarchical logistic regression was run with by-word random intercepts, as well as by-speaker random slopes (weight) and intercepts. Like in the Portuguese model, LLL was the reference level for weight and default priors were used. The model's estimates confirm what is observed in **Figure 3**, namely, that relative to LLL words, LHL words affect

[8] Several variables would need to be controlled for an analysis of reaction times across stress profiles, which is not the focus of the present paper; see Garcia and Guzzo (2022) for a recent study examining this question.

speakers' responses, reducing the probability of preference for antepenultimate stress. HLL words have a slightly negative effect on speakers' preference for antepenultimate stress, but the posterior distribution is too close to zero for us to confidently conclude that antepenultimate heavy syllables have an effect—as shown in **Figure 4**, zero is not only included in the 95% credible interval, but also in the 50% credible interval of the posterior distribution.

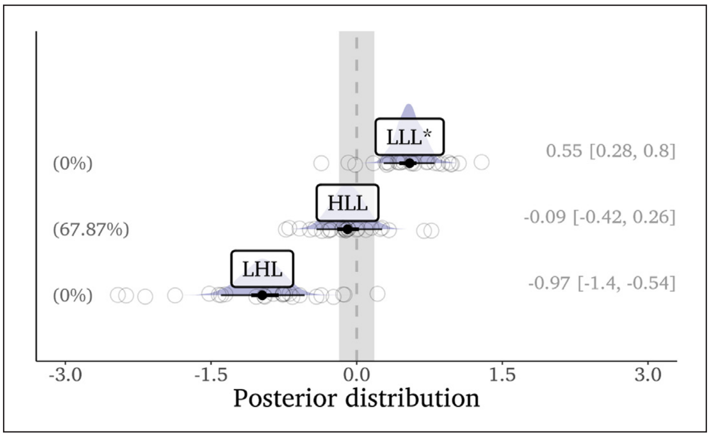

Figure 4: Parameter estimates and associated posterior distributions for English. The intercept is indicated with an asterisk. Credible intervals are shown in the figure and detailed on the right (mean [95% highest density interval, or HDI]). The percentage of each HDI that is contained within the ROPE (shaded area around 0.0) is shown on the left.

Table 4 lists the mean estimates (Mean $\hat{\beta}$) as well as the 95% credible intervals in the posterior distributions estimated. For example, the mean $\hat{\beta}$ for the intercept (0.55) represents the mean of the posterior distribution for this parameter (in log-odds)—the positive intercept captures the preference for antepenultimate stress in LLL words, as observed in **Figure 3**. The 95% credible interval in question goes from 0.28 (2.5%) to 0.81 (97.5%).

Table 4: English model. Mean parameter estimates and associated estimated errors, credible intervals, $\hat{R}$, and ESS (n_{eff}).

Parameter	**Mean $\hat{\beta}$**	**Est Error**	**2.5%**	**97.5%**	**$\hat{R}$**	**n_{eff}**
Intercept (LLL)	0.55	0.14	0.28	0.81	1.0	2188
HLL	–0.09	0.17	–0.43	0.25	1.0	2263
LHL	–0.97	0.22	–1.42	–0.56	1.0	2085
MODEL: `stress ~ weight + (1+weight|participant) + (1|word)`						

As we can see from the table, the mean estimate for HLL is negative (–0.09). The 95% credible interval of its posterior distribution ranges from –0.43 to 0.25. As a result, the distribution includes zero as a credible parameter value. Given that our reference level is LLL, this means that the effect of HLL words is mostly negative relative to LLL words, but that we cannot conclude that these two weight profiles have reliably different effects on the basis of our model. The results for English thus show no credible effect of weight in antepenultimate syllables—indeed, 68% of the HDI of HLL is located within the ROPE in **Figure 4**.

On the other hand, the posterior distribution of LHL excludes zero, and has a mean of –0.97. This is the log-odds of antepenultimate stress given a LHL word (relative to a LLL word). Simply put, a LHL word lowers the odds of antepenultimate stress by a factor of 2.6 ($e^{|\hat{\beta}|}$). If we again pick mean($\hat{\beta}$) as a single point estimate, the overall probability of choosing antepenultimate (over penultimate) stress in LHL words is 27% (compared to 63% for LLL words).

We point out finally that, as with the Portuguese data discussed earlier, certainty levels and reaction times did not show any particular trends for antepenultimate stress preference in HLL versus LLL words in our English data.

4.3. Language comparison

In this section, we compare the main findings for the two languages. To facilitate this, we combine both languages into a single figure of posterior distributions of effect sizes. **Figure 5** overlays the two central models discussed thus far (Portuguese is shown in white; English is shown in violet). Both LLL* and HLL effects are included, given that we must interpret the HLL distributions relative to those of LLL* in each language.

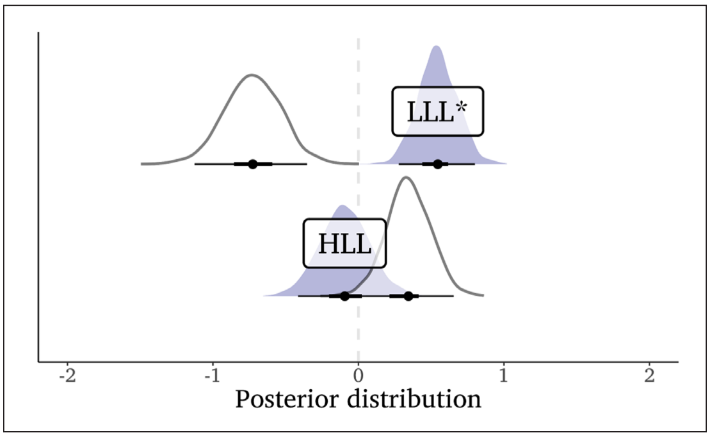

Figure 5: Posterior distributions of HLL: Portuguese (white) versus English (violet). Portuguese displays a clear positive posterior distribution for HLL (relative to LLL*); English displays a distribution centered around zero.

First, we point out that the LLL* distributions are on opposite sides of the null effect line ($\hat{\beta} = 0$). This is consistent with the patterns in each language: antepenultimate stress is much less common than penultimate stress in Portuguese, but much more common in English.[9] Second and more crucially, the distributions of HLL are fundamentally different: positive in Portuguese, but centered around zero in English. Note that we cannot directly compare the HLL distributions in both languages in the figure, since the effects are always relative to the posterior distribution of the intercept, LLL*.

4.4. Sonority effects

We have seen that the results for Portuguese and English parallel each other insofar as both languages display a positive weight effect for penultimate position. The languages differ for antepenultimate position: Portuguese exhibits a positive effect for weight in this position while English does not, as shown in **Figure 5**. In this section, we show that the difference between the two languages extends to sonority effects, which can be detected in HLL words in Portuguese but not in English.

4.4.1. Sonority effects in Portuguese

In the Portuguese experiment, we find that type of coda (sonorant vs. obstruent) in antepenultimate position has an effect on speakers' preferences for antepenultimate stress. This is shown in **Figure 6**, which plots the preference for antepenultimate stress (*y*-axis) by weight profile and coda type—means and bootstrapped confidence intervals are provided.

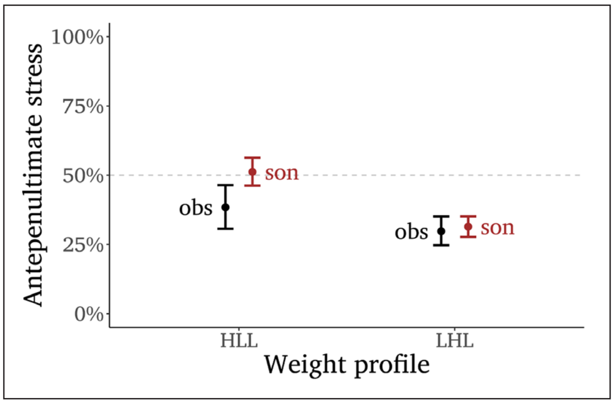

Figure 6: Effect of coda type on stress preference in Portuguese.

[9] See Garcia (2019) for discussion of the learned status of words with antepenultimate stress in Portuguese and how this can prime speakers to favor words with said stress in an experimental setting.

To confirm the effect of coda type observed in **Figure 6**, a model was run with main effects as well as the interaction of weight and coda type (sonorant or obstruent). The model includes by-speaker random slopes for sonority and its interaction with weight, and by-item random intercepts. LLL words, where no coda effect can be assessed, were excluded. The model is shown in **Table 5**. We can see a statistically credible effect of coda (son): $\hat{\beta} = 0.40$. This effect refers to HLL words (the reference sonority level in the model), and confirms what we observe in **Figure 6**. Of interest, the sonority effect we detected remains if we exclude stimuli with coda /l/, which is vocalized to [w]: $\hat{\beta} = 0.42$. Thus, if participants were interpreting vowel + /l/ sequences as diphthongs, this possibility would not change the overall sonority effect found in the data.

Parameter	Mean $\hat{\beta}$	Est Error	2.5%	97.5%	$\hat{R}$	n_{eff}
Intercept (HLL, obs)	–0.68	0.27	–1.20	–0.16	1.0	2434
LHL	–0.60	0.29	–1.15	–0.03	1.0	2757
coda (son)	0.40	0.21	0.00	0.82	1.0	2826
LHL:coda (son)	–0.31	0.31	–0.93	0.30	1.0	2758
MODEL: `stress ~ weight * coda + (weight*coda|participant) + (1|word)`						

Table 5: Sonority model for Portuguese. Mean parameter estimates and associated estimated errors, credible intervals, $\hat{R}$, and ESS (n_{eff}).

4.4.2. Sonority effects in English

Given the sonority effect observed for Portuguese, we must question whether a similar effect might be found in English. Any effect in the latter language would likely be relatively smaller, given the absence of a positive correlation between syllable weight and antepenultimate stress.

Parallel to **Figure 6** for Portuguese, **Figure 7** plots the preference for antepenultimate stress (*y*-axis) by weight profile and coda type for English—means and bootstrapped confidence intervals are provided. As already seen in **Figure 3**, antepenultimate stress is not statistically affected by the weight of an antepenultimate syllable. Here, we see that the sonority value of antepenultimate (and penultimate) codas does not appear to affect the preference for antepenultimate stress in the data.

To model the effect of coda type in HLL and LHL words in English, a model was run with main effects as well as the interaction of weight and coda type (sonorant or obstruent). This is the same model that was used to examine sonority in the Portuguese data above. Thus, the model excludes LLL words, where no coda effect can be assessed. In addition, by-speaker random slopes for the interaction and random intercepts, as well as by-word random intercepts, were added.

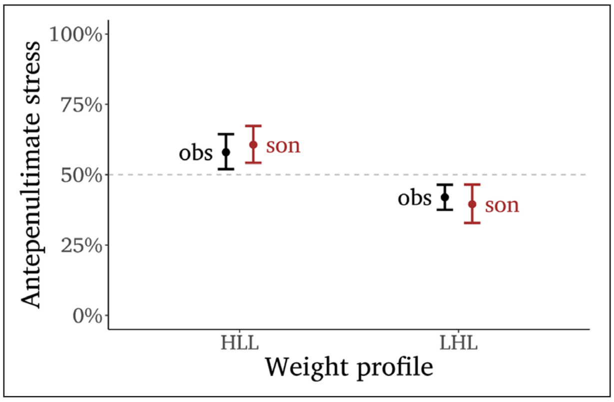

Figure 7: Effect of coda type on stress preference in English.

The results are shown in **Table 6**, and can be summarized as follows: for HLL words with a sonorant coda (*coda (son)* in the table), we have a posterior distribution with mean $\hat{\beta} = 0.30$, although $\hat{\beta} = 0$ is included in the 95% credible interval of the distribution, which is consistent with what we see in **Figure 7**. Only one effect is statistically credible given all the 95% credible intervals in question (LHL), which is neither surprising (given what we have seen thus far) nor relevant to our discussion: LHL words with an obstruent coda reduce the probability of preferring antepenultimate stress relative to HLL words with an obstruent coda.

Parameter	**Mean $\hat{\beta}$**	**Est Error**	**2.5%**	**97.5%**	**$\hat{R}$**	**n_{eff}**
Intercept (HLL, obs)	0.30	0.20	–0.09	0.69	1.0	2354
LHL	–0.66	0.25	–1.14	–0.17	1.0	2383
coda (son)	0.30	0.19	–0.08	0.68	1.0	2737
LHL:coda (son)	–0.44	0.28	–0.99	0.09	1.0	2563
MODEL: `stress ~ weight * coda + (weight*coda|speaker) + (1|word)`						

Table 6: Sonority model for English. Mean parameter estimates and associated estimated errors, credible intervals, $\hat{R}$, and ESS (n_{eff}).

4.5. Predictions revisited

In sum, we have seen that weight effects are present in antepenultimate syllables in Portuguese, but not in English. We have also detected a sonority effect in antepenultimate codas in Portuguese, but not in English, which provides a more nuanced picture of weight effects in this position. Although sonority effects are not the main object of examination in the present paper, these findings contribute to the discussion on sonority-driven stress, which has typically focused on sonority (height) in vowels (e.g., McCollum, 2020; Shih, 2015; Shih & de Lacy, 2019). We will consider the implications of sonority more concretely in the discussion (Section 6).

Given the cross-language difference concerning weight effects in antepenultimate position, we address the main results discussed above in light of our predictions (see Section 3.4). Recall that English is a language for which there is strong evidence for moraic trochaic footing (Section 2.2). On the basis of this, we predicted that English would either show a negative weight effect in antepenultimate position, where stressed light syllables are preferred over stressed heavy syllables (ĹLL ≻ H́LL), or a null weight effect in said position (ĹLL = H́LL). Consistent with this prediction, we experimentally confirmed a neutral weight effect in antepenultimate position for English.

In contrast, following earlier work by Garcia (2019), we predicted that Portuguese would show a positive weight effect in antepenultimate position, where speakers generalize the effects of weight from penultimate and final positions and thereby prefer stressed heavy syllables over stressed light syllables (H́LL ≻ ĹLL). We suggested that such a result would challenge the role of the (moraic trochaic) foot in regulating stress in Portuguese because there is no optimal parse that prioritizes foot well-formedness for H́LL strings. Recall in this context that earlier research does not agree on the type of feet that Portuguese builds (Section 2.1). Consistent with the stated prediction, we experimentally confirmed a positive weight effect in antepenultimate position for Portuguese.

5. Beyond stress: word minimality

Thus far, we have suggested that the neutral weight effect found for antepenultimate position in English speakers' grammars supports a foot-based approach to stress in this language. At the same time, parallel experimental results found a positive weight effect for antepenultimate position in Portuguese speakers' grammars, which may challenge a foot-based approach to stress in that language. If our interpretation of these cross-language differences is along the right lines, we should expect to find other prosodic phenomena that support and call into question the role of the foot in English and Portuguese, respectively. In this section, we provide additional evidence along these lines, from minimal lexical words, as well as from patterns of hypocorization and truncation.

We have seen that feet play a central role in earlier metrical approaches to stress in Portuguese and English. Given that lexical words are prosodic words, that prosodic words must contain at least one foot, and that feet strive to be binary to be well-formed, if Portuguese and English build feet, we would expect lexical words in both languages to minimally contain two syllables or two moras—a condition known as *word minimality* (McCarthy & Prince, 1995; see also Hayes, 1995). Foot binarity has been shown to strictly regulate word size in some languages, but Garrett's (1999) typological study has uncovered other languages where mismatches are observed: languages where the minimal word can be smaller or larger than the minimal foot (see also Piggott, 2010); as well as languages where minimal word restrictions hold but where stress is not conditioned by foot structure. These languages have led Garrett to conclude that minimal word constraints are not grounded in foot structure. In light of Garrett's findings, coupled with the observation that some languages do show a correspondence between foot structure and minimal word shape, we contend that if one of the languages under present focus were to show that lexical words are not constrained by foot binarity, it would be Portuguese, the language where evidence for footing is the weakest. As we will see, this is indeed what we find.

5.1. Portuguese

5.1.1. Minimal lexical words

Subminimal lexical words are common in Portuguese: over 70% of all possible CV combinations are found in the language. Representative examples are provided in **Table 7**. Many such words, including those in the table, are frequent, as can be inferred from their meanings. This would appear to pose a problem for metrical approaches to Portuguese stress, since lexical words that are smaller than a binary foot are seemingly freely tolerated in the language.

Word	Gloss	Word	Gloss
chá	'tea'	*rí*	'laugh.IMP'
dó	'pity'	*pé*	'foot'
fé	'faith'	*pó*	'dust'
má	'bad (f)'	*nú*	'nude'
nó	'knot'	*só*	'lonely'

Table 7: Common CV words in Portuguese.

In and of itself, however, the existence of CV words may not be a substantial problem. After all, it is possible that subminimality is not productive in Portuguese, and is therefore restricted to lexical items for which a diachronic explanation can be found, namely, the loss of final codas and/or declensions (see Veloso, 2018). Although this explanation holds for some CV words (e.g., *só* from Latin *sōlus* 'alone'), it predicts that speakers of Portuguese should not generalize the CV pattern to other constructions. This, however, is not the case, as we will see in the following section on hypocorization.[10]

First, though, we must take another look at the data in **Table 7**. The generalization that subminimal lexical words are freely permitted in Portuguese only holds true when we consider CV words, not monomoraic words more generally; what is missing from the language is lexical words that are V in shape. V-shaped words are confined to function words, onomatopoeia, interjections, and the names of vowels. From this, we can conclude that there *is* a word minimality condition on Portuguese lexical words; however, word minimality does not make reference to optimal feet but, rather, to optimal syllables. The finding that word minimality is respected in Portuguese but that it does not refer to bimoraicity casts doubt on a role for the foot in this language.

5.1.2. Hypocorization

In his work on hypocorization in Portuguese, Gonçalves (2004) proposes that the melodic material in names is mapped to a moraic trochaic template to form the hypocoristic. Although this seems to be supported for several hypocoristics, like those in column (a) in **Table 8**, outputs such as those in column (b), where hypocorization results in a monomoraic output, are also very common in the language. As might be expected, some bisyllabic hypocoristics alternate with monomoraic forms: *Fabiána → Fábi ~ Fá*.

(a)	Name	Hypocoristic	(b)	Name	Hypocoristic
	Gabriéla	Gábi		Fernánda	Fé
	Isabél	Bél		Guilhérme	Guí ([gi])
	Rafaél	Ráfa		Luciána	Lú
	Robérto	Béto		Tiágo	Tí

Table 8: Hypocoristic patterns in Portuguese.

The data in (b) thus demonstrate that words that are smaller than a binary foot are productively generated in Portuguese. However, as was the case for subminimal lexical words, it seems that hypocoristics must be minimally CV in size. Speakers' judgments of the well-formedness of V-shaped hypocoristics are uncertain. For example, speakers seem to prefer that *Hugo* [úgu] not have a hypocoristic, rather than truncating the name to [u]. This provides additional support for a minimal word constraint that targets the syllable, rather than the foot, in Portuguese.

[10] Portuguese differs in this respect from Japanese. In Japanese, a handful of subminimal lexical words are attested (e.g., *ya* 'arrow'; *ko* 'child'), but word minimality is respected in truncated hypocoristics as well as in shortened loan-words. Itô (1990) argues that word minimality in Japanese is enforced as a lexical constraint (Kiparsky, 1985) and, therefore, it does not affect underived words.

In addition to the monomoraic forms in column (b) in **Table 8**, other outputs that depart from bimoraic trochees are observed in hypocorization in Portuguese. Specifically, when hypocoristics are reduplicated, both iambic and trochaic shaped outputs are found: *Viviane* → *Viví* ~ *Vívi*; *Bibiana* → *Bibí* ~ *Bíbi*. Indeed, in contrast to the pattern in (a) in **Table 8**, there seems to be a preference for iambs, as all trochaic reduplicated hypocoristics can also be realized as iambs, but not the other way around: *Luciána, Luíza* → *Lulú* but **Lúlu*; *Fátima*, *Fabiána* → *Fafá* but **Fáfa*. Since trochees are more restricted than iambs in such cases, this weakens the argument that trochees are the main metrical pattern in Portuguese.

5.1.3. Truncation

The inconsistency of foot types proposed in previous analyses of stress in Portuguese can also be observed in truncation; **Table 9** shows that both iambic (a) and trochaic (b) profiled outputs emerge in truncated forms. In fact, minimal pairs can even be found: *professór* 'teacher' → *prófi*, but *profissionál* 'professional' → *profí* (or *pró*). Araújo (2002) proposes that the stress pattern in these truncated forms can be predicted from the location of secondary stress in the source word. In *pròfessór*, secondary stress is found word-initially; thus, the truncated form bears penultimate stress: *prófi*. In this case, the resulting metrical structure corresponds to a trochaic foot. The stress pattern in the truncated form of *profissionál*, on the other hand, is faithful to the secondary stress in the peninitial syllable of the source word: *profí*. In this case, the resulting metrical structure corresponds to an iambic foot.

	Word	**Truncated form**	**Footing**
(a)	*refrìgeránte* 'soda'	refrí	trochee → iamb
	dèpressáo 'depression'	depré	trochee → iamb
(b)	*cervéja* 'beer'	cé(r)va	trochee → trochee
	neuróse 'neurosis'	néura	trochee → trochee

Table 9: Truncation patterns in Portuguese.

Although the position of secondary stress can account for *refrìgeránte* → *refrí*, it fails to account for *dèpressáo* → *depré* (**dépre*).[11] It is also challenged by the fact that the location of secondary stress can vary in Portuguese. For example, *profissional* can be pronounced as *profissionál* or as

[11] Araújo (2002) argues that *depré* is a case of pseudo-truncation, since the source word cannot be unambiguously determined. Unlike in the other cases discussed, where the source word is clear, in the case of *depré*, both *dèpressáo* 'depression' and *dèprimída* 'depressed' can be the source word. Note, though, that the resulting prosodic shape is not predictable from either possible source word.

pròfissionál and *refrigerante* can be pronounced as *refrìgeránte* or as *rèfrigeránte*. We thus need to assume that *profissionál* is the source of *profí* and that *refrìgeránte* is the source of *refrí*.

In short, the patterns of truncation discussed here show little metrical consistency, as both iambs and trochees are generated, sometimes under the same conditions. Furthermore, as just seen, secondary stress in Portuguese is not necessarily rhythmic, an observation that may challenge the existence of feet in the language.

5.1.4. Summary

We have seen that no robust empirical evidence for a consistent metrical structure exists in Portuguese, neither for determining where stress falls in the stress window nor for restricting the shapes of smaller words. Concerning stress, ambiguity in the language has led researchers to propose moraic and syllabic trochees, and trochees and iambs. Although heavy syllables gradiently attract stress (Garcia, 2017a), we have experimentally confirmed that Portuguese speakers generalize weight effects to antepenultimate position, which challenges the role of the (trochaic) foot in regulating stress. Consequently, if footing is what led to ĹLL words being more frequent than H́LL words in the Portuguese lexicon in the past, it seems that this preference is not reflected in the synchronic grammar of the language—at least not in Standard Brazilian Portuguese. These inconsistencies have important implications for language acquisition, as learners attempting to construct a grammar for Portuguese may have difficulty establishing which foot type accurately characterizes the language. In fact, Ferreira-Gonçalves (2010) observes that words with both iambic and trochaic profiles are found in children's early productions, suggesting that no particular foot shape is emerging as optimal from the input. Turning to the shapes of smaller words in Portuguese, similar inconsistencies are found in patterns of truncation, which result in iambic- or trochaic-shaped outputs, depending on the word being analyzed. A related challenge is that CV words are commonly attested in the lexicon and, crucially, in hypocorization, which indicates that derived words that are smaller than a binary foot are productive; indeed, word minimality makes reference to syllable well-formedness, rather than to foot well-formedness. Taken together, these findings are not what we would expect from a language that unequivocally builds feet.

5.2. English

The experimental results summarized above for Portuguese contrast with what we observed for English, namely, a neutral effect for weight in antepenultimate position. The latter finding is consistent with English building feet, a proposal that has not, to our knowledge, been challenged in the literature on stress in this language. As the cross-linguistic difference we have experimentally demonstrated may reflect a different status for the foot in the two languages, we must determine whether English shows minimal word, truncation, and hypocorization effects distinct from those in Portuguese, specifically, patterns that are consistent with the language building binary moraic trochees. In the following section, we show that this is indeed the case.

5.2.1. Minimal lexical words, truncation, and hypocorization

Unlike Portuguese, where lexical words that are smaller than a binary foot are commonly attested, English has no such words: every lexical word must have at least two moras. This restriction bans (C)V words, but allows (C)VV and (C)VC as the smallest lexical words. Accordingly, *bee* [biː] and *bit* [bɪt] are well-formed, but *[bɪ] is not. Such word minimality constraints are straightforwardly captured if English builds moraic trochees and every foot is binary.

Word minimality also regulates truncation and hypocorization in English. Truncation never yields subminimal outputs: *bro(ther)*, *sis(ter)*, and *ad(vertisement)* all have two moras: [broʊ], [sɪs], [æd], respectively, but never *[brʌ], *[sɪ], *[æ]. The same holds true of hypocoristics: *Edward*, *Elizabeth*, and *Joseph* are shortened to [ɛd], [bɛθ] or [lɪz], and [d͡ʒoʊ], and never to *[ɛ], *[bɛ]/*[lɪ], or *[d͡ʒo]/*[d͡ʒʌ]. These comparisons illustrate the interaction between vowel length, weight, and footing: feet in English must be bimoraic to be licit, and this has consequences for the shapes of the truncated forms we observe in the language.

5.2.2. Summary

The patterns discussed above all motivate footing in English. Crucially, the non-existence of monomoraic lexical words is consistent with the assumption that the language builds binary trochaic feet.[12] In combination with our experimental findings of an interaction between stress and weight (positive in penultimate position and neutral in antepenultimate position), all evidence supports a consistent metrical structure for the language.

6. Discussion

We have argued that whereas English provides strong evidence for footing, Portuguese does not. First, stress in English is regulated by both optimal footing and weight-sensitivity. Heavy syllables attract stress, except in antepenultimate position as this would result in a marked metrical structure: an unparsed syllable in the middle of the word, (H́)L⟨X⟩, or an uneven trochee, (H́L)⟨X⟩. Stress in Portuguese, on the other hand, does not appear to motivate footing. Weight effects are observed in all three syllables in the stress domain (Garcia, 2017b). Therefore, while weight effects are present in antepenultimate position in Portuguese, they seem to be absent

[12] Monomoraic lexical words are absent from English but subminimal lexical words may not be. Potential examples of the latter include CV́CV words like *city*. In such cases, building a binary foot conflicts with extrametricality: both (CV́CV) and (CV́)⟨CV⟩ are viable parses. The existence of exceptional final stress, however, indicates that extrametricality can be violated in English. In contrast, the fact that monomoraic lexical words are not attested in the language indicates that foot binarity cannot be. As a result, the optimal parse for words like *city* must be (CV́CV).

from this position in English. Second, sonority effects are found in antepenultimate position in Portuguese, but not in English. Given that sonority effects represent a fine-grained manifestation of weight-sensitivity, we expect that a language like English, whose metrical optimization is more strictly based on foot structure, will minimize such effects relative to a language like Portuguese, where stress is seemingly not constrained by constituency. Finally, while word minimality effects are observed in both languages, only in English does the minimal word correspond to a binary foot. In Portuguese, it corresponds instead to an optimal (CV) syllable.

If it is plausible that the foot plays no role in Portuguese, this would, of course, mean that the foot is not a universal constituent of the prosodic hierarchy. This possibility is implied in McCarthy & Prince (1995), but is argued against in Selkirk (1996) and Vogel (2010). While the universality of the foot has been questioned by some researchers, this has typically been for languages like Turkish and French, which lack the characteristic signatures of word-level stress. We briefly consider each in turn.

Regular stress in Turkish is typically described as being word-final, yet the cues to prominence involve only a slight rise in f0, which is often absent altogether; exceptional stress, in contrast, is marked by greater intensity and a steep f0 rise (Konrot, 1981; Levi, 2005; Pycha, 2006; Vogel et al., 2016). Vogel et al. (2016) suggest that the weak cues in final position may indicate that Turkish lacks lexical stress. This could indicate that Turkish words, at least those with regular stress, do not project feet, which is the position defended by Özçelik (2014) (see also Kabak & Vogel, 2001, whose analysis of Turkish does not employ feet). Özçelik argues that suffixes that display exceptional stress enter the derivation as footed. His proposal captures the range of behavior they display, and is consistent with the cue profile observed. Regular stress is instead intonational prominence and thereby does not implicate the foot. Since not all Turkish words contain an irregular suffix, of course, a key consequence of Özçelik's proposal is that the foot cannot be a universal constituent of the prosodic hierarchy (Özçelik, 2014, 2017).

Turning to French, the domain of obligatory prominence is the phonological phrase (PPh) rather than the PWd (e.g., Dell, 1984), which has led many researchers either to avoid positing the foot (Jun & Fougeron, 2000; Mertens, 1987) or to explicitly reject this constituent (Andreassen & Eychenne, 2013; Özçelik, 2017). However, although French does not have lexical stress, other patterns in the language have been argued to motivate the foot. Focusing on Québec French, feet are implicated in, for example, truncation patterns (Scullen, 1997) and schwa realization in compounds (Charette, 1991); further, iterative footing is proposed to account for patterns of high vowel deletion (Guzzo et al., 2018, building on Verluyten, 1982), and possibly high vowel laxing (Lamontagne, 2020). We thus consider Québec French to have a foot, even if this constituent does not regulate stress.

An important difference holds between English and Portuguese on one hand and Turkish and French on the other: the first two languages have lexical stress; the latter two (according to some researchers) do not. If the foot is absent from Portuguese, this would indicate that even languages with seemingly “ordinary” patterns of prominence could cast doubt on a foot-based analysis of stress and, thus, that despite apparent similarities in their stress patterns, English and Portuguese could differ fundamentally in their prosodic representations.

From the preceding discussion, it appears that the presence/absence of feet in a language is formally independent of the presence/absence of lexical stress. This conclusion is consistent with previous work arguing that prominence and foot structure are formally distinct entities (e.g., van der Hulst, 2012; Vaysman, 2009). Indeed, our central claim in this paper has been that English and Portuguese both have lexical stress, but differ in terms of the empirical evidence that motivates the foot—little to none in Portuguese, considerable in English. Conversely, French and Turkish may both lack lexical stress, but they also differ in terms of the empirical evidence available that could motivate the foot. Taken together, if Portuguese lacks the foot, we arrive at the typology in **Table 10**:

Foot	Lexical stress	Language
yes	yes	English
no	yes	Portuguese?
yes	no	(Québec) French
no	no	Turkish

Table 10: Foot and lexical stress typology.

A question that arises from our approach is whether a more appropriate analysis of the typology in **Table 10** would be to assume that all languages have the foot and that cross-linguistic differences emerge from differences in the ranking (or weighting) of optimality-theoretic constraints. This approach would be in the spirit of the original version of OT, where constraints were assumed to be universal: innate and present in the grammars of all languages; further, since constraints can take prosodic constituents like the foot as arguments, these constituents were also assumed to be universal (Prince & Smolensky, 1993/2004). We focus the discussion on regulating the role of the foot in languages with lexical stress, namely English versus Portuguese.

We adopt the position that constraints are weighted rather than ranked (Pater, 2009), which better captures the probabilistic behavior that languages display (Boersma & Pater, 2016; Goldwater & Johnson, 2003; Hayes & Wilson, 2008; Wilson, 2006). This is consistent with what we have observed for stress in both Portuguese and English and for prosodic phonology more generally in Portuguese. We sketch an analysis along the following lines: FootBinarity (Feet are binary) would have a robustly higher weight in English than in Portuguese; NonFinality (No foot is final in PWd) would have a moderately higher weight in English than in Portuguese; and Weight-to-Stress would be gradiently interpreted for each syllable in the stress domain, with relatively stronger effects in final and antepenultimate positions in Portuguese than in English and relatively stronger effects in penultimate position in English than in Portuguese. Concerning FootForm, English would allow one foot type only (FootForm(Troch) highly weighted), while in Portuguese, both FootForm(Troch) and FootForm(Iamb) would be operative, with lexically-specific constraints playing a critical role in determining the stress profile of any given word or construction type (e.g., CV-shaped hypocoristics).

Although an analysis along these lines could be posited, it does not, in our view, inform our understanding of the patterns present in Portuguese. If instead the foot is not operative in this language, then constraints on foot well-formedness are not expected to regulate stress nor any other prosodically-conditioned process like hypocorization, which is what we have observed, in stark contrast to English.

One problem for this approach would seem to be constraining the window in which primary stress falls. Earlier in the paper, we mentioned that in most languages, stress is located within a trisyllabic window from a word edge (Gordon, 2016; Kager, 2012). Following Hayes (1980), this has typically been captured via a bisyllabic foot plus one additional (extrametrical) syllable at an edge (although this is not without empirical challenges; see Kager, 2012; van der Hulst, 2012). As a trisyllabic window holds for Portuguese as well as for other languages where the foot has been questioned (e.g., Vietnamese; Schiering et al., 2010), we must employ some other mechanism to ensure that the window is appropriately constrained. Following Gordon (2002), we adopt the view that rhythmic constraints regulate the distance between primary stress and a word edge.

Gordon (2002) employs a grid-based rather than a foot-based model of stress assignment (see earlier Prince, 1983; Selkirk, 1984). Within this framework, he proposes that stress windows arise from the relative ranking of anti-lapse constraints (see also Elenbaas & Kager, 1999; Green & Kenstowicz, 1995). For a language like Portuguese, where the stress window is maximally three syllables at the right word edge, the operative constraint would be *ExtendedLapseRight, which prohibits more than two stressless syllables between the rightmost stress and the right word edge. As stress can fall anywhere within the three-syllable window, additional constraints are required (we focus on LLL words, thus leaving Weight-to-Stress aside). If AlignHeadLeft and AlignHeadRight (Kager, 2012; adapted from Gordon, 2002) are highly weighted, this will favor *σ́σσ* and *σσσ́*, respectively. To ensure that *σσ́σ* can be selected, AlignHeadRight must yield to NonFinality (redefined as stress does not fall on the final syllable), which will favor *σσ́σ* over *σσσ́*; and AlignHeadLeft must yield to *LapseRight (a maximum of one unstressed syllable separates the rightmost stress from the right edge of a stress domain), which effectively shortens the window, thereby selecting *σσ́σ* over *σ́σσ*.

Although anti-lapse constraints can successfully define the stress window for footless languages, Kager (2012) has questioned the validity of this family of constraints. The central argument concerns "midpoint pathology":[13] if symmetrical anti-lapse constraints (*ExtendedLapseLeft and *ExtendedLapseRight) are highly ranked such that the same three-syllable window is respected at left and right edges, satisfaction of both constraints will lead to stress being trapped on the medial syllable (in five-syllable words), which is unattested. Kager thus removes anti-lapse from the inventory of constraints which, if valid, leaves us with no explanation for the three-syllable window in which primary stress is found in languages without feet. An alternative approach is taken by Stanton (2016). She demonstrates that systems with midpoint pathology are likely not generalized by learners because they are difficult to acquire. Such systems can thus be excluded from the expected typology of languages on learnability grounds rather than on formal grounds, thereby circumventing the need to expunge anti-lapse from the inventory of constraints available. We follow Stanton in preserving anti-lapse and assume that such constraints serve to limit the stress window in languages that lack feet, which we have proposed may be the appropriate way to characterize Portuguese.

The final question we address stems directly from the non-universal status attributed to the foot: is there precedence for positing that phonological primitives more generally are not universal? Our position would be strengthened if we could show that there is nothing unusual about the foot in this regard.

A growing community of linguists is questioning whether phonological primitives that were formerly considered to be universal truly have this status (Blevins, 2004; Harris, 2007; Pierrehumbert, 2003; Schiering et al., 2010). At the segmental level, many have recently proposed that features are not innate (e.g., Clements & Ridouane, 2011; Dresher, 2014; Mielke, 2008; Pulleyblank, 2006) but, instead, emerge based on learners' experience with articulation and perception and with phonological patterns present in the data to which they are exposed. Further, since the universality of constraints has been questioned (e.g., Hayes, 1999), and since constraints can take features and prosodic constituents as arguments, this opens up the possibility that, at the prosodic level, constituents other than the foot may not be universal as well. The most likely candidate for non-universal status is the mora: it need not be projected in languages where all syllables are light. As for the syllable, this constituent is absent in Government Phonology (Kaye et al., 1990), and its existence has been questioned by those working in phonetically-driven phonology (e.g., Steriade, 1999); both of these approaches open up the possibility that the syllable may not be universal (if present at all). As for higher level constituents—PWd, PPh and IP (intonational phrase)—given that these have syntactic analogs (see, e.g., Selkirk's 2011 Match constraints), they could be argued to be universal. However, their existence has also been challenged, either individually (e.g., Schiering et al. (2010) on the absence of the

[13] Another empirical challenge for anti-lapse constraints that Kager attributes to Hyde (2008) comes from languages like Maithili where the three-syllable window identified for primary stress can be interrupted by another stress: this additional stressed syllable will not be factored into the calculation of lapse violations.

PWd in Vietnamese), or more generally, by researchers who assume that syntactic phases alone determine phonological domains (e.g., Newell, 2017). Clearly, determining the (non)universal status of individual primitives requires more work, but our goal here is to show that it is unlikely that the foot must be singled out.

If the foot is not innate, it must be projected by learners on the basis of the evidence to which they are exposed. We might be tempted to conclude that this evidence would be the phonetic cues normally associated with the presence or absence of stress: strings over which pitch, duration and intensity are modulated. Clearly, though, this cannot be the only consideration; on one hand, languages with no convincing evidence for the foot employ these cues for stress; on the other hand, modulation of pitch, at a minimum, is implicated in tone languages (independent of footing) and in intonational tunes. To project the foot, what is necessary is evidence that a binary headed domain (bimoraic or bisyllabic) regulates phonological behavior, potentially including but not limited to stress. We have shown that evidence for such a domain is weak in Portuguese, in spite of the surface similarities in stress patterns that hold between this language and English. Future empirical work must be undertaken on languages that have lexical stress but may lack feet.

Additional files

The following OSF repository contains an R script as well as all the data and model files necessary to reproduce the analysis in this paper: https://osf.io/3cvrm/

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Competing interests

The authors have no competing interests to declare.

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