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Acoustic evidence for affix classes: A case study of Brazilian Portuguese

RESEARCH

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ABSTRACT

In languages that assign stress differently according to morphological structure, affixes often fall into different categories. In Brazilian Portuguese, normal suffix words have one stress (Base: [kaˈfɛ] 'coffee'; suffixed: [kafe-ˈtejɾa] 'coffee pot'). Special suffix words are claimed to have two stresses, one of which falls in the same location as in the independent base ([kaˌfɛ-ˈzĩɲu] 'coffee-DIM'). The special suffixes include diminutive -*(z)inho*, superlative -*íssimo*, and adverbial -*mente*. This paper reports on a production study showing that stress maintenance on the base of special suffix words is acoustically present through longer duration and marginally higher intensity, and through maintenance of vowel height for mid vowels. Phonologically, the special suffixes are often analyzed as attaching to an independent prosodic word base (e.g. Collischonn 1994; Moreno 1997; Vigário 2003; Guzzo 2018). I cast the analysis in Distributed Morphology (Halle & Marantz 1993): the phonological differences between special and normal suffixes are due to morphosyntactic differences. Under this analysis, differences between special and normal suffixes are principled rather than arbitrary. Morphological and prosodic structure are both necessary, and prosodic structure mediates between morphology and phonological processes.

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1 INTRODUCTION

This paper investigates the relationship between word formation and stress assignment. Some languages assign stress predictably in both simple and morphologically complex words, without regard to morphological structure (e.g. Pintupi, Hansen & Hansen 1969; see also Gordon 2002 and references within). Other languages, like English and Russian, have morphologically sensitive stress assignment. In these languages, affixes affect stress differently. English Level 1 affixes like *-al, -ous, -ity,* and *-ic* can change the location of stress on the base (e.g. *ségment, segmént-al*), while Level 2 suffixes like *-hood, -ness, -ism, -ist, -able,* and *-ful* are stress-neutral, leaving the stress in the same location as in the independent base (e.g. *síster, síster-hood*) (Kiparsky 1982; Halle & Mohanan 1985, among others). However, the division between Level 1 and Level 2 affixes is debated and does not always make the correct and necessary distinctions between affixes (Bauer et al. 2013; Arndt-Lappe 2014). Russian diminutives provide another example of morphologically sensitive stress assignment. Three diminutive allomorphs are morphosyntactically similar (Steriopolo 2008), but differ in whether they are stress neutral ([-ik], [-tʃʲik]; Base: [ˈmonstr], DIM: [ˈmonstr-ʲik]), or attract stress onto themselves ([-ok]; Base: [ˈangʲil] 'angel', DIM: [angʲil-ˈok]) (Gouskova, et al. 2015). In Russian, diminutives have to be treated as arbitrarily different in stress properties. Still other approaches to stress in morphologically complex words use decomposibility and frequency to predict gradient patterns, rather than dividing affixes into discrete categories (Collie 2008; Hedia & Plag 2017).

Affixes may pattern together phonologically for arbitrary reasons, or their shared phonological properties may be related to shared morphological properties. In theories like Benua (1997)'s output-output faithfulness, affix classhood is arbitrary: the affixes in a phonological class do not necessarily share morphological characteristics. Other work posits a close relationship between morphological structure and phonological processes (e.g. Marvin 2002; Oltra-Massuet and Arregi 2005). Stress patterns can reflect morphological structure because cyclic spell-out is determined by morphology, allowing phonology to apply in stages as a word is built. These theories make different predictions about which affixes in a language should pattern together, and these predictions remain largely unexplored in experimental research.

I present a case study of Brazilian Portuguese, investigating acoustic evidence of two affix classes often posited in the literature. Brazilian Portuguese assigns stress differently in morphologically simple and complex words, and stress assignment depends on the suffix. Lee (1992) extends the level ordering built for English (Siegel 1974; Allen 1978) to Brazilian Portuguese, dividing affixes into Level 1 and Level 2 based on the application of phonological processes. This division does not correlate with different stress assignment. Grouping affixes into "stem-level" vs. "word-level" (Villalva 1994; Moreno 1997) correlates better with stress assignment, essentially dividing suffixes into *special* and *normal*. **Normal suffixes** attach to the stem and integrate prosodically with it (e.g. *-eiro, -ista, -mento*). Primary and secondary stress are assigned to the entire word as if it were morphologically simple. The **special suffixes**—diminutive *-(z)inho*, superlative *-íssimo*, and adverbial *-mente*— do not integrate prosodically with the base, and are said to maintain stress on the base as if it were an independent word. These suffixes are "word-level."

The phonological differences between words with special and normal suffixes can be analyzed as deriving from morphological differences. I analyze these suffixes using Distributed Morphology (DM, Halle & Marantz 1993), in which morphological representations feed cyclic spell-out, providing principled reasons for differences in stress assignment. In DM, roots acquire grammatical category by merging with category-assigning heads (Halle & Marantz 1993). These heads trigger spell-out, sending the material beneath them to phonology as a unit (Marantz 2001; Marvin 2002). Morphological structure thus determines which parts of words undergo phonology together or separately. The special suffixes in Brazilian Portuguese attach to already-categorized roots while normal suffixes attach to uncategorized roots. My analysis follows Bachrach & Wagner (2007) on Brazilian Portuguese diminutives and extends it to superlatives, which are morphologically similar. However, adverbial *-mente* differs morphologically from diminutives and superlatives. I analyze diminutives and superlatives as modifiers that attach outside categorizing heads, thus falling outside the preceding spell-out domain and undergoing phonology separately from their bases. Stress is assigned to the base to the exclusion of the suffix. In contrast, *-mente* is a root that forms a morphological and

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(nested) phonological word compound with its base. Despite this difference, all of the special suffixes attach outside the first categorizing head, resulting in the shared phonological property of maintaining stress on the base.

My production study provides acoustic evidence of phonological patterns tied to morphological structure. Stress maintenance on the base of special suffix words is often assumed, but there is little supporting acoustic evidence. To preview, the results show that stress maintenance on the base shows up in duration and intensity (with effect sizes modulated by vowel quality), and in vowel height for mid vowels only. For duration, the effect is strongest for mid vowels and weaker in low and high vowels. The intensity differences are small but systematic for vowels of all qualities.

The remainder of the paper is as follows. Section 2 provides information on the Brazilian Portuguese vowel inventory, stress, and special and normal suffix words. Section 3 provides a morphological and phonological analysis of the special suffixes. Then, Sections 4 and 5 present the methodology and results of the production study. Section 6 addresses why acoustic evidence of stress maintenance is strongest for mid vowels, and discusses the acoustic findings in relation to other theories of phonology and morphology. Section 7 concludes.

2 BACKGROUND

2.1 BRAZILIAN PORTUGUESE VOWEL INVENTORY AND STRESS

The Brazilian Portuguese vowel inventory differs based on stress level. In primary stressed syllables, there are seven vowels /a, ɛ, e, i, u, o, ɔ/. In most varieties of Brazilian Portguese, the mid vowel height distinction (/ɛ/ vs. /e/ and /ɔ/ vs. /o/) is neutralized in favor of the upper-mid vowel ([e, o]) in unstressed pretonic syllables, reducing the inventory to five vowels (Câmara 1970a; Bisol & Veloso 2016; Rodrigues & da Hora 2016). For example, the lower-mid vowel in [ˈpɛdɾa] (‘stone’) becomes upper-mid in a suffixed word [peˈdɾ-ejɾu] (‘mason’), when primary stress shifts off it.[1] In some Northern and Northeastern varieties, the result of mid vowel height neutralization is instead lower-mid vowels (Schwindt 2013; Bisol & Veloso 2016; Santana 2019). The current study excludes speakers from these regions. Finally, final unstressed mid and high vowels neutralize to [i, u] in most varieties, further reducing the inventory in these positions ([a, i, u]) (Câmara 1970a; Major 1985; Mateus & d’Andrade 2000; Barbosa & Albano 2004; Crosswhite 2004).

Primary stress in Brazilian Portuguese falls within a trisyllabic window at the right edge of the word and can be penultimate ([izoˈlada] ‘isolated’), antepenultimate ([ˈvalida] ‘valid’), or final ([maɾakuˈʒa] ‘passionfruit’). Many scholars argue that primary stress assignment is weight-sensitive for non-verbs (e.g. Bisol 2010; Wetzels 2007; Garcia 2017). Penultimate stress is considered default (Câmara 1970b; Wetzels 2007): when all syllables are light, stress is almost always penultimate (Garcia 2017). Garcia (2017) argues that antepenultimate and final stress can be partially predicted by the shapes of the final three syllables. However, stress can also be contrastive, indicating that it is lexically marked at least in some cases (e.g. [ˈsabja] ‘wise’ vs. [saˈbja] ‘kind of bird’ vs. [saˈbi.a] ‘3SG knew’).

Secondary stress assignment depends on the number of pretonic syllables in morphologically simple words. Words with an even number of pretonic syllables have alternating, binary secondary stress ([ˌpĩdaˌmoɲãˈgaba] ‘place name’) (Lee 2002). Words with an odd number of pretonic syllables either have alternating, binary secondary stress ([aˌbakaˈʃi] ‘pineapple’) or initial prominance ([ˌabakaˈʃi]) (Collischonn 1994). In most morphologically complex words, regular secondary stress is assigned as in morphologically simple words (1)–(2) (Collischonn 1994).

1 Throughout the paper, I use broad phonetic transcription and omit details that are not directly relevant. This makes it easier for readers familiar with Brazilian Portuguese to recognize the words, and for readers unfamiliar with the language to focus on the relevant details. When referring to Portuguese, I mean Brazilian Portuguese unless otherwise specified. I transcribe orthographic coda <r> as a tap for consistency. Coda <r> production varies widely depending on region and includes taps, glottal fricatives, and retroflexes (Cristófaro Silva 1998; Cardoso et al. 2014). Finally, I consistently transcribe /t, d/ as palatalized before the high front vowel ([tʃi, dʒi]), since this process is almost categorical in most varieties of Brazilian Portuguese (Abaurre & Pagotto 2002).

(1) Regular secondary stress in suffixed words with odd number of pretonic syllables (adapted from Collischonn 1994)

	Base	Suffixed		Gloss
		Binary	Initial	
a.	esˈkãdalu	esˌkãdaˈl-ozu	ˌeskãdaˈl-ozu	‘scandalous’
b.	sisteˈmatʃika	sisˌtemaˌtʃis-iˈdadʒi	ˌsistemaˈtʃis-iˈdadʒi	‘systematicity’

(2) Regular secondary stress in suffixed words with even number of pretonic syllables

a.	poziˈtʃivu	ˌpoziˌtʃiv-iˈdadʒi	—	‘positivity’

Many theories of metrical stress are designed to capture secondary stress assignment, but experimental research often fails to find supporting acoustic evidence of this stress. Studies of languages as diverse as Spanish (Romance; Prieto & van Santen 1996; Díaz Campos 2000; Hualde & Nadeau 2014), Polish (Slavic; Newlin-Lukowicz 2012), Pitjan-tjatjara (Pama-Nyungan; Tabain et al. 2014), and Indonesian (Polynesian; Adisamito-Smith & Cohn 1996) do not find robust acoustic evidence to verify impressionistic reports of secondary stress. In Brazilian Portuguese, the evidence is also limited and inconsistent in both production (Gama Rossi 1998; Moraes 2003; Arantes & Barbosa 2006) and perception (Moraes 2003; Keller 2004). My production study also finds no evidence of regularly assigned, rhythmic secondary stress and I do not discuss it further.

2.2 SPECIAL AND NORMAL SUFFIX WORDS

In Brazilian Portuguese, most suffixes are normal suffixes like *-eiro, -ista, -mento, -oso, – (i)dade*. They integrate prosodically with the base: primary stress is assigned to the entire word as a single unit, falling within the final trisyllabic stress window. Secondary stress also applies to the word as a whole (see (1)–(2)).

Special suffixes are a closed class that consists of the diminutive *-inho/-zinho*, the superlative *-íssimo*, and the adverbial suffix *-mente*.[2] The form of the diminutive is determined mostly by the phonological shape of the base.[3] *-zinho* typically attaches to words with final stress ([kaˈʒu], [kaˌʒu-ˈzĩɲu]) or antepenultimate stress ([esˈkãdalu], [esˌkãdalu-ˈzĩɲu]), but can also attach to words with penultimate stress ([aˈmigu], [aˌmigu-ˈzĩɲu]). With *-zinho*, the theme vowel is always maintained (underlined) ([amig-u-ˈzĩɲu]). *-inho* and *-íssimo* attach to bases with penultimate or antepenultimate stress, and the theme vowel deletes ([kaˈlad-a], [kaˌlaˈdʒ-ĩɲa]; [ˈvalid-a], [ˌvaliˈdʒ-isima]). *-mente* attaches to adjectives (which have penultimate or antepenultimate stress) and maintains the theme vowel ([kaˌlad-a-ˈmẽtʃi]). The diminutives also differ from each other in another respect: when the theme vowel mismatches with the gender of the word, *-inho* maintains the theme vowel of the base, while *-zinho* takes the theme vowel of the gender, regardless of the base theme vowel. For example, a masculine word like *o problem-a* (‘the problem’) has a masculine determiner /o/, but /a/ as the theme vowel (instead of canonical masculine /o/). The *-inho* diminutive maintains the theme vowel of the base (*o problem-inh-a*), while *-zinho* takes the canonical theme vowel corresponding to the gender of the word (*o problem-a-zinh-o*). This suggests some difference in attachment. See Lee (2013), Armelin (2014) and Ulrich (2016) for more discussion.

2.2.1 Stress in special suffix words

Words with special suffixes are thought to have stress in the same location as in the independent base: the strongest stress falls on the suffix, but a stress still falls on the stressed base vowel. For example, in (3c), a base like [ʒeneˈɾɔza] is described as having stress on [ɾɔ] in the special suffix word [ʒeneˌɾɔza-ˈmẽtʃi], even though primary stress falls on the suffix. This is opposed to regular secondary stress assignment in the same bases with normal suffixes ([ˌʒeneˌɾozi-ˈdadʒi]). Although the location of regular secondary stress and stress maintenance on the base can coincide in this example, vowel quality distinguishes the two.

2 Augmentatives also fall into this class, but are beyond the scope of the current study. See Zani (2009) and Armelin (2014) for more on augmentatives.

3 There is some debate about whether *-inho* is an allomorph of *-zinho* (e.g. Menuzzi 1993; Bisol 2010) or a distinct suffix (e.g. Brakel 1981; Moreno 1997; Lee 2013).

(3) **Special suffixes maintain stress in the same place as it falls in the independent base; normal suffixes do not**

	Base	Special suffix	Gloss	Normal Suffix	Gloss
a.	eˈzɛɾsitu	eˌzɛɾsitu-ˈzĩɲu	'army-DIM'	ˌezeɾˌsita-ˈdoɾ	'exerciser'
b.	ˈvalida	ˌvalida-ˈmẽtʃi	'valid-ADV'	ˌvalida-ˈsɐ͠w ~ vaˌlida-ˈsɐ͠w	'validation'
c.	ʒeneˈɾɔza	ʒeneˌɾɔza-ˈmẽtʃi	'generous-ADV'	ˌʒeneˌɾozi-ˈdadʒi	'generosity'

The surface realization of stress can differ from this assigned stress in two ways. First, words with special suffixes variably undergo stress retraction to avoid stress clash ([kaˌfɛˈzĩɲo] → [ˌkafɛˈzĩɲo]) (Lee 2013; Guzzo 2018). Second, the regular secondary stress algorithm can variably reapply at the word-level in special suffix words, resulting in retraction or advancement that modifies the apparent location of the stress on the base. While most scholars agree that stress retracts in clash, there is disagreement on whether it can *advance* (Menuzzi 1993; Lee 2002; 2013). Guzzo (2018: 22) reports advancement in addition to retraction: a word like [ˌasidu-ˈzĩɲu] ('acid-DIM') typically has a secondary stress in the same location as stress falls in the independent base ([ˈasidu]), but reapplication of the secondary stress algorithm at the word-level can also result in [aˌsidu-ˈzĩɲu]. A reviewer suggests that reapplication of the secondary stress algorithm in special suffix words may vary dialectally. However, even when stress retracts in special suffix words, stressed base lower-mid vowels maintain their quality, highlighting a difference between stress maintenance ([ˌkafɛˈzĩɲo]) and regularly assigned secondary stress ([ˌkafeˈtejɾa]) (Lee 2002; Guzzo 2018). Despite theoretical claims about stress retraction and advancement in Brazilian Portuguese, there is little acoustic evidence for it. Madureira (2002) finds no significant difference in duration or pitch (f0) in clash and non-clash syllables across word boundaries, concluding that stress shift is optional and stylistic. Furthermore, vowel duration in Brazilian Portuguese increases monotonically moving towards primary stress (Gama Rossi 1998; Arantes & Barbosa 2002), suggesting that retraction does not manifest through duration.

2.2.2 Vowel reduction as a stress diagnostic

The vowel inventory of Brazilian Portuguese depends on stress, so changes in vowel quality are used as evidence of stress level. Three processes affect unstressed vowels: (a) mid vowel height neutralization (Bisol & Veloso 2016); (b) denasalization (Lee 2013); (c) pretonic vowel raising (Bisol & Veloso 2016; Ulrich 2016). All are blocked in special suffix words for vowels that are stressed in the independent base, suggesting that they are also stressed in special suffix words.

Recall that the mid vowel height contrast (/e/ vs. /ɛ/, /o/ vs. /ɔ/) is maintained only in stressed syllables. Since lower-mid vowels occur only in stressed syllables, the presence of lower-mid vowels on the base of words with special suffixes indicates stress maintenance. Vowel reduction to [e, o] suggests lack of stress. In (4), the lower-mid vowels [ɛ, ɔ] in the base reduce pretonically in normal suffix words but are maintained in words with special suffixes.

(4) **Special suffixes block mid vowel neutralization**

	Base	Normal suffix		Special suffix	
a.	/kaˈfɛ/	kafe-ˈtejɾa	'coffee pot'	kaˌfɛ-ˈzĩɲu	'coffee-DIM'
b.	/abɾiˈkɔ/	abɾiko-ˈteiɾu	'apricot tree'	abɾiˌkɔ-ˈzĩɲu	'apricot-DIM'

Denasalization is also blocked in special suffix words for vowels that are stressed in the independent base. Stressed vowels undergo extensive anticipatory nasalization before an onset nasal ([ˈkãma] 'bed'), but unstressed vowels do not ([kaˈmĩɲa] '3SG walks'). The anticipatory nasalization of [ˈkãma] is maintained in its diminutive [ˌkãˈm-ĩɲa] 'bed-DIM,' even though primary stress shifts to the suffix (Lee 2013). The lack of denasalization suggests that the base vowel maintains stress; if it were not stressed, we would expect denasalization. For comparison, there is no nasalization in [kaˈmĩɲa] '3SG,' since the first vowel is unstressed.

Finally, pretonic vowel raising is blocked in special suffix words for vowels that are stressed in the independent base. Pretonic raising is typically treated as height harmony conditioned by a high vowel in the following syllable, and applies mostly to unstressed vowels (Bisol 1981). For example, normal suffix words related to the base /ˈveɾde/ ('green') allow variable raising of the pretonic vowel when primary stress shifts off it ([viɾˈd-uɾa] ~ [veɾˈd-uɾa] 'vegetable'). However, special suffixes block raising ([ˌve̲ɾˈdʒ-ĩɲu], *[ˌvi̲ɾˈdʒ-ĩɲu]), suggesting that the vowel is stressed at some level (Toneli 2014; Ulrich 2016).

3 ANALYSIS

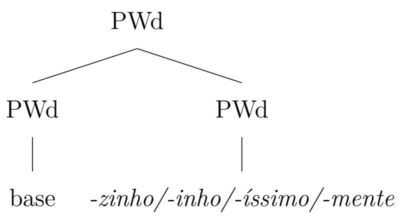
This section provides background on previous phonological and morphological analyses of the special suffixes (Sections 3.1 and 3.2). Then I present my analysis of diminutives and superlatives (Section 3.3) and adverbial *-mente* (Section 3.4). In my analysis, morphological structure determines cyclic spell-out, resulting in different stress patterns for normal and special suffixes (following Bachrach & Warner 2007). Specifically, categorizing heads trigger spell-out of material beneath them. I analyze diminutives and superlatives as modifiers that attach above the categorizing heads of their bases. Adverbial *-mente* is a root that forms a morphological and phonological compound with its base. Like diminutives and superlatives, it attaches above the categorizing head of its base; unlike diminutives and superlatives, it is also its own independent prosodic word. By attaching outside the head that categorizes the base, all of the special suffixes allow the base to undergo phonology to the exclusion of the suffix. In contrast, normal suffixes are the realization of the categorizing head, and undergo phonology together with the base. The differences in stress assignment between special and normal suffix words follow from the morphosyntactic differences in place and manner of attachment. Section 3.5 provides a brief summary of the analysis.

3.1 PREVIOUS PHONOLOGICAL ANALYSES OF SPECIAL SUFFIXES

The special suffixes are often analyzed as independent prosodic words that receive stress and undergo reduction separately from their bases (e.g. Brakel 1981; Moreno 1997; Vigário 2003; Bachrach & Wagner 2007; Lee 2013; Schwindt 2013; Ulrich 2016; Guzzo 2018; Ulrich & Schwindt 2018). Similar arguments have been made for Italian (Vogel & Scalise 1982) and Spanish (Harris 1983; Roca 1986; Crowhurst 1992). While the three languages have many similarities, Spanish and Portuguese adverbials differ from Italian adverbials in several informative ways (see Section 3.4).

In most analyses of Portuguese, the special suffixes form compound prosodic word structures (Menuzzi 1993; Moreno 1997; Lee 2002; Vigário 2003; Quadros & Schwindt 2008; Schwindt 2013; Toneli 2014; Guzzo 2018). That is, both the base ([kaˈlada]) and the suffix ([-ˈmẽtʃi]) are prosodic words nested within a larger prosodic word: [[kaˈlada]ω[ˈmẽtʃi]ω]ω. This is illustrated in (5).

(5) Special suffix words analyzed as nested prosodic words (adapted from Guzzo 2018: 31)



Guzzo (2018) argues that special suffix words are prosodized recursively within the prosodic word domain, resulting in a larger prosodic word to which post-lexical processes—like regular secondary stress—can apply.[4] Special suffix words differ from word-word compounds like *guarda-chuva* ('umbrella,' lit. 'keep-rain'; Guzzo 2018), which are not prosodized recursively within the prosodic word domain, and have slightly different stress assignment. However, in Guzzo's (2018) account, both special suffix words and word-word compounds consist of multiple prosodic words. Maintenance of vowel quality in the base follows naturally, since stress and vowel reduction apply to each part independently.

4 Stress retraction and advancement (Section 2.2.1) are not counterarguments to stress maintenance on the base, or independent prosodic word status of the parts. Secondary stress assignment is said to be post-lexical, applying after word formation (Collischonn 1994; Lee 2002; Bachrach & Wagner 2007). The base and special suffix can be prosodic words with individually assigned stress, regardless of later post-lexical adjustments on surface stress.

The most straightforward phonological argument that special suffix words contain an independent prosodic word base is vowel height (F1) in pretonic and base-final vowels. As discussed in Section 2.2, mid vowel height contrasts are not neutralized in special suffix words, if the vowel is stressed in the independent base. Additionally, base-final vowels in special suffix words undergo extreme reduction as if they were word-final. Portuguese has different degrees of vowel reduction: word-final vowel reduction is extreme, while word-internal unstressed vowel reduction is less so (Crosswhite 2004). For example, word-final /o/ in /amigo/ reduces to [u] ([aˈmigu]), and the extreme reduction is maintained in the diminutive ([aˌmigu-ˈzĩɲu]). This suggests a prosodic word boundary after the base in the special suffix word (Toneli 2014; Ulrich 2016; Guzzo 2018).

Scholars generally agree that *-zinho* and *-mente* attach to independent prosodic word bases and are independent prosodic words themselves (Menuzzi 1993; Moreno 1997; Lee 2002; Vigário 2003; Quadros & Schwindt 2008; Schwindt 2013; Toneli 2014; Guzzo 2018). There is less agreement about the *-inho* form of the diminutive and *-íssimo*, which some authors argue to behave like normal suffixes with regard to secondary stress (Menuzzi 1993; Collischonn 1994; Moreno 1997; Lee 1999; 2013). This appears to hold of European Portuguese (Villalva & Gonçalves 2016). However, all four suffixes block mid vowel height neutralization in Brazilian Portuguese (Quadros & Schwindt 2008; Ulrich 2016; Ulrich & Schwindt 2018).

To preview, my analysis departs from analyses that treat all special suffix words as nested prosodic word compounds. In my analysis, all bases are independent prosodic words, but *-mente* is the only suffix that is itself a prosodic word. Diminutive and superlative suffixes attach to a prosodic word base, but are not *themselves* independent prosodic words.

3.2 MORPHOLOGICAL CHARACTERISTICS OF SPECIAL SUFFIXES

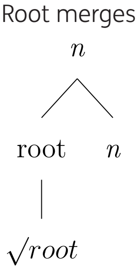
Words with special suffixes contain an independent prosodic word base while normal suffixes form a single phonological word with their bases. Can we account for this difference in a principled way? Is there a morphological characteristic that groups the special suffixes together, to the exclusion of normal suffixes? In frameworks like Distributed Morphology, morphological structure and phonological structure are linked: prosodification cycles are defined by syntactic domains. Indeed, the special suffixes differ morphologically from normal suffixes in place and manner of attachment.

I briefly present the Distributed Morphology framework (Halle & Marantz 1993) (Section 3.2.1) and discuss diagnostics for place and manner of attachment (Section 3.2.2), before sketching the analysis of diminutives/superlatives and adverbial *-mente* (Sections 3.3 and 3.4). DM provides a principled way of explaining the prosodic output. It is not inconsistent with prosodic phonology, but comes in at an earlier step to connect structure to prosody.

3.2.1 Distributed Morphology

Distributed Morphology (DM) (Halle & Marantz 1993) builds on Derivation by Phase (Chomsky 2001), which assumes a modular view of the grammar: syntactic and morphological operations occur first, and then send material to phonology. DM assumes that words have an internal syntax and are formed in the syntax by the same mechanisms used to form sentences. Phonological material spells out in phases determined by morphological structure. Various frameworks (Halle & Marantz 1993; Borer 2014) assume that roots have no category of their own, but rather acquire it by merging with category-assigning heads (6). DM assumes that speakers have lexical knowledge about the root and which categories it combines with (Marantz 2001).

(6) Root merges with categorizing head



A crucial element of DM is that the prosodic structure of a word is related to its hierarchical syntactic structure. The mapping between morphological and prosodic structure is indirect, and mediated by phonological constraints. In some langauges, the mapping is less direct than in others. In Russian, for example, prepositions that are morphosyntactically identical can differ in phonological behavior. Gouskova (2019) argues that the morphology-phonology mapping must be able to occur in three places in the grammar: (1) in the morphosyntax: constituents derived by movement are marked as phonological words; (2) in the lexicon: some morphemes are marked as phonological words; (3) in the phonology: phonology considers information from both morphosyntax and the lexicon, but phonological constraints can override it in determining surface prosodic word structure. In other languages, the mapping between morphological and phonological structure is more direct. For example, stress assignment can be derived from cyclic, phase-based spell-out of morphological structure in languages like English (Marvin 2002), Cupeño (Uto-Aztecan; Newell 2008), Turkish (Newell 2008), Spanish (Oltra-Massuet & Arregi 2005) and Portuguese (Bachrach & Wagner 2007). Stress assignment follows from principled interactions between morphosyntax and phonology. Category heads like *n(oun), a(dj), v(erb)* are phase heads that trigger spell-out (Marantz 2001; Marvin 2002; Embick 2010). At spell-out, the material contained in the head and in its sister is sent to phonology as a chunk and undergoes phonological processes as a unit. Some morphologically complex words are treated as a single phonological unit, while others are treated as multiple units because they are spelled out in chunks. For Brazilian Portuguese, the morphosyntactic component provides the necessary information for phonological word formation.

DM is not inconsistent with prosodic phonology. Prosodic phonology also assumes that morphology informs phonology, and that the mapping is indirect (e.g. Selkirk 1995). In DM, prosodic words are formed based on morphological structure; they are due to cyclic spell-out and a separation between the morphological and phonological components of the grammar. DM maps morphological information to a surface prosodic structure, providing a structural basis for the resulting prosodic structure. The instructions for *how* prosodic words are formed are language specific: some languages can be analyzed as having syntactic nodes that are marked to create phonological words (Svenonius 2016), while others, like Russian, require syntactic node marking, lexical information, and phonological constraints to result in the correct prosodic word formation (Gouskova 2019).

A structural account for Brazilian Portuguese diminutives has advantages over a purely phonological account. In DM, the different behavior of special and normal suffixes is a consequence of how the morphosyntactic structure passes information to the phonology. Phonological words follow from morphology, and this prosodic structure mediates between morphology and phonological processes like mid vowel reduction. Special suffixes do not select for prosodic word bases, but bases end up being independent prosodic words due to cyclic spell-out.

3.2.2 Diagnostics for place and manner of morphological attachment

Wiltschko & Steriopolo (2007), Bachrach & Wagner (2007), and Steriopolo (2008; 2015) lay out diagnostics to evaluate two dimensions of morphological attachment that affect spell-out: *manner* (head vs. modifier) and *place* (to root vs. to already-categorized root). For *manner* of attachment, heads affect the formal features of the base (e.g. category, gender, conjugation class), and cannot be repeated. Modifiers, on the other hand, do not affect the category or gender of the base, and can be repeated. For *place* of attachment, suffixes can attach to a bare root, inside number/gender inflection and theme vowels. Alternatively, they can attach to an already-categorized root, and can differ in location with regard to number, gender, theme vowels, and other suffixes. Steriopolo (2015) analyzes Spanish diminutives—which are very similar to Brazilian Portuguese diminutives—as modifiers that adjoin to categorized roots.

For *place* of attachment, I analyze Brazilian Portuguese special suffixes as attaching to already-categorized roots, while normal suffixes attach to bare roots. This is similar to Villalva's (1994) analysis of *-zinho* as a modifier that attaches to a morphological word.[5] Bachrach & Wagner (2007) also analyze diminutives as attaching to an already-categorized root within a DM framework, but they do not detail the connection between morphology and phonology.

5 Villalva's (1994) account differs from the current account, however, in terms of *-inho* and *-íssimo*. In her account they attach to roots, but in the current account they attach to phonological words.

Several diagnostics indicate that special suffixes attach outside categorizing heads. All of the special suffixes attach outside number marking, plural marking, and derivational suffixes, implying prior categorization. Diminutives and superlatives can attach outside plural marking on the base. This is widely reported for the *-zinho* diminutive (e.g. Lee 1999; Bachrach & 2007), but also holds for *-inho* and superlatives.[6] Number marking inside and outside diminutives and superlatives is visible because pluralization causes several changes to the base (7). In some cases, pluralization changes the final segment of the base ([ʒoɾˈnaw] → [ʒoɾˈnaj-s], 7a) (Lee 1999; Bachrach & Wagner 2007). It can also change the quality of a base vowel ([ˈnovu] → [ˈnɔvu-s], 7b, d) (Moreno 1997: 176), or the quality of the final nasal diphthong ([koɾaˈsɐ̃w̃] → [koɾaˈsõj̃-s], 7c) (Moreno 1997: 153). Whatever changes are made in the plural base are maintained in the plural diminutive (Moreno 1997; Lee 1999; Bachrach & Wagner 2007). Normal suffixes never attach to bases with plural marking (7e).

(7) Number marking in special and normal suffixes

		Singular		Plural	
		Base	Suffixed	Base	Suffixed
Diminutive					
a.	‘newspaper’	ʒoɾˈnaw	ʒoɾˌnaw-ˈzĩɲu	ʒoɾˈnaj-s	ʒoɾˈnaj-ˈzĩɲu-s
b.	‘pig’	ˈpoɾku	ˌpoɾˈk-ĩɲu	ˈpɔɾku-s	ˌpɔɾˈk-ĩɲu-s
c.	‘heart’	koɾaˈsɐ̃w̃	koɾaˌsɐ̃w̃-ˈzĩɲu	koɾaˈsõj̃-s	koɾaˌsõj̃-ˈzĩɲu-s
Superlative					
d.	‘new’	ˈnovu	ˌnoˈv-isimu	ˈnɔvu-s	ˌnɔˈv-isimu-s
Normal					
e.	‘newspaper,’ ‘journalist’	ʒoɾˈnaw	ʒoɾnaˈl-ista	ʒoɾˈnaj-s	ʒoɾnaˈl-ista-s

Gender inflection shows the same pattern as number inflection. Feminine inflection on the base results in a vowel change from the masculine form ([o] →[ɔ]). Again, this vowel change on a feminine base is maintained in feminine diminutives, superlatives, and adverbials (8a–c). Normal suffixes never attach to already-inflected bases: no matter which form of the base is assumed for a normal suffix word, the pretonic vowels are always upper-mid when primary stress is on the suffix (8d).

(8) Gender marking in special and normal suffixes

		Masculine		Feminine	
		Base	Suffixed	Base	Suffixed
Diminutive					
a.	‘new’	ˈnov-u	ˌnoˈv-ĩɲ-u	ˈnɔv-a	ˌnɔˈv-ĩɲ-a
Superlative					
b.	‘new’	ˈnov-u	ˌnoˈv-isim-u	ˈnɔv-a	ˌnɔˈv-isim-a
Adverbial					
c.	‘new’	—	—	ˈnɔv-a	ˌnɔva-ˈmẽtʃi
Normal					
d.	‘pretty’	ˈbel-u	—	ˈbɛl-a	beˈl-eza

Finally, special suffixes attach outside normal suffixes; the reverse order is not possible (9). If normal suffixes are categorizing heads, then this is further evidence that the special suffixes attach to already-categorized roots. Adverbial *-mente* also attaches outside diminutives and superlatives, suggesting even higher morphological attachment ([kaladʒ-ˌ ˌisima-ˈmẽtʃi], [*kalada-menˈtʃ-isima]).

6 Brakel (1981) and Lee (1999) indicate that there is variability in whether pluralization appears inside diminutives. Lee (1999) further speculates that speakers do not always pluralize inside diminutives in everyday speech. What is crucial here is that it is an option.

(9) Normal suffixes (bold) and special suffixes (underlined)

	Base		Suffixed	Unattested	
Diminutive					
a.	dẽˈtʃ-**ista**	'dentist'	dẽtʃ-**is**ˈ**t**ʃ-ĩɲa	*dẽtʃ-ĩɲ-ˈ**ista**	(Armelin 2014)
			√dent-**suff**-DIM	*√dent-DIM-**suff**	
Superlative					
b.	noˈʒ-**ẽtu**	'disgusting'	noʒ-ẽˈ**t**ʃ-ĩsimu	*noʒ-isiˈm-**ẽtu**	
			√noj-**suff**-SUP	*√noj-SUP-**suff**	
Adverb					
c.	kaˈl-**ada**	'quiet'	kal-**ada**-ˈmẽtʃi	*kala-mẽt-**ada**	
			√kal-**suff**-ADV	*√kal-ADV-**suff**	

To summarize place of attachment, diminutives, superlatives and adverbial *-mente* attach to categorized roots, outside number and gender. Normal suffixes attach to uncategorized roots, inside number and gender.

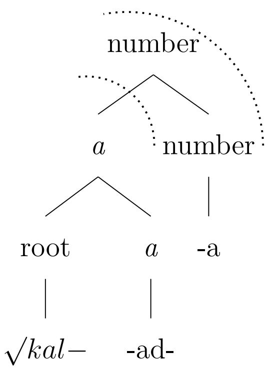
Diminutives and superlatives further differ from normal suffixes in *manner* of attachment (Villalva 1994). Diminutives and superlatives do not change the category or gender of the base (e.g. [pɾoˈblema] and [probleˈm-ĩɲa] 'problem-DIM' are both nouns) and can be repeated (e.g. [bɔl-ĩɲa-ˈzĩɲa] 'ball-DIM-DIM'; [lĩdʒ-iˈs-isima] 'pretty-SUP-SUP'). Normal suffixes determine the category of the derived word (e.g. [ˈnovu] 'new-ADJ', [nov-iˈdadʒi] 'piece of news-NOUN'), and cannot be repeated ([dẽˈtʃ-ista], *[dẽtʃ-ist-ista] 'dentist'). These differences suggest that diminutives and superlatives are modifiers, while normal suffixes are heads that determine formal features of the derivative, like gender and grammatical category (following Bachrach & Wagner 2007 on diminutives).

Adverbial *-mente* differs from both derivational suffixes and the other special suffixes in manner of attachment. Unlike diminutives and superlatives, it is not a modifier. Like normal suffixes, it changes the category of the base (ADJ → ADV) and cannot be repeated. However, despite the morphological difference, *-mente* patterns phonologically with diminutives and superlatives. Some accounts of *-mente* argue that it is changing from an independent word to bound affix (Silva et al. 2008; Duarte 2009), and classify it vaguely as a "suffixoid." In Section 3.4, I argue that it forms a morphological compound with its base.

3.3 ANALYSIS: DIMINUTIVES AND SUPERLATIVES

In a DM framework, place and manner of attachment affect which chunks of material are spelled out together. For manner, I follow Villalva (1994) and Bachrach & Wagner (2007) in treating diminutives in Brazilian Portuguese as morphological modifiers. For Bachrach & Wagner (2007), diminutives attach as modifiers outside the categorizing head of the base (11). Normal suffixes, in contrast, are the realization of the categorizing head (10). This corresponds with category-changing behavior: diminutives and superlatives do not affect the category of their bases, while normal suffixes do. The trees in (10) and (11) are adapted from Bachrach & Wagner (2007).

(10) Structure for derivational suffixes



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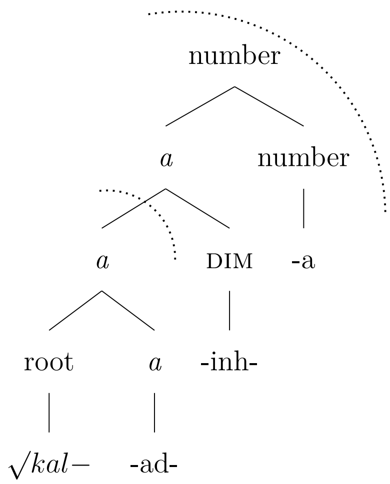
(11) Structure for *-inho/-issimo* suffixes (attaching inside number inflection)



Spell-out domains are marked in the trees. Categorizing heads trigger spell-out (Marantz 2001; Marvin 2002), sending all material in that node and its sister to phonology. Normal derivational suffixes (*-ad-* in (10)) attach to roots as the realization of a category-assigning head (*a*), which triggers spell-out of itself and its complement (√*kal* + *-ad-*). This chunk—root + normal suffix—is assigned stress as a whole because morphology feeds it to phonology as a unit. Special suffixes are different (11). The suffixes *-inho/-issimo* attach outside the categorizing head as modifiers, not affecting the category of the base. The base (√*kal* + *-ad-*) is sent to phonology to the exclusion of the special suffix, and undergoes phonology. The stress assigned to the base at this stage is maintained even after the suffix is added.

Recall that diminutives and superlatives can also attach outside number and gender marking (Section 3.2.2). Bachrach & Wagner (2007) allow an additional place of attachment above the first number phrase for diminutives (12), which can be extended to superlatives since they allow similar number and gender marking on the base. Like in (11), spell-out in (12) occurs at the categorizing head, sending the base to spell out separately from the special suffix.

(12) Structure for *-zinho*, which can attach outside number inflection (adapted from Bachrach & Wagner 2007)

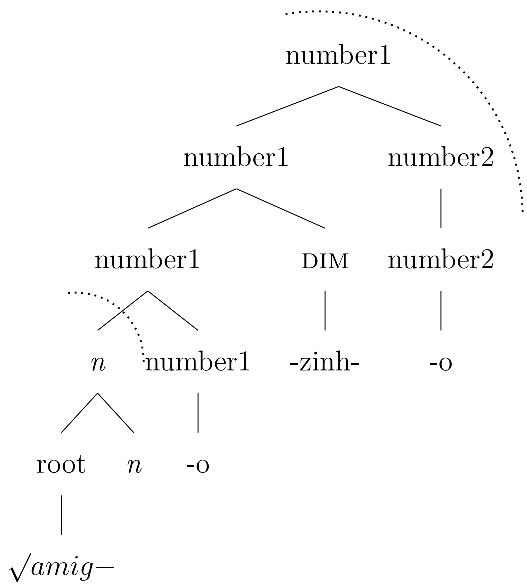


Table (13) illustrates the cyclic interaction of phonology and morphology determined by the tree structure. The input to (13a) is a tree like (12); the input to (13b) is a tree like (10). While the roots and suffixes used in the trees differ, they are of the same structure. This derivation differs from a strictly Lexical Phonology account with level ordering. The apparent levels result from morphological structure, and the phonological results depend on how much of the word is present at specific points of the derivation.

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(13) Cyclic spell-out and phonology. Brackets indicate morphological material present for phonology at the given derivation step.

	a. Special Suffix	b. Normal Suffix
Underlying	/kaˈfɛ/ + /-zĩɲo/	/kaˈfɛ/ + /-tejɾa/
Affixation (1st categorizing head)	[kaˈfɛ]ω-zĩɲo	[kaˈfɛ-tejɾa]ω
Stress	[kaˈfɛ]ω-zĩɲo	[kaˈfɛ-ˈtejɾa]ω
One main stress per word	[kaˈfɛ]ω-zĩɲo	[kafɛ-ˈtejɾa]ω
Neutralization	[kaˈfɛ]ω-zĩɲo	[kafe-ˈtejɾa]ω
Word-level secondary stress	[kaˈfɛ]ω-zĩɲo	[ˌkafe-ˈtejɾa]ω
Affixation (2nd categorizing head)	[[kaˈfɛ]ω-zĩɲo]ω	–
Stress	[[kaˈfɛ]ω-ˈzĩɲo]ω	–
One main stress per word	[[kaˌfɛ]ω-ˈzĩɲo]ω	–
Neuralization	[[kaˌfɛ]ω-ˈzĩɲu]ω	–
Word-level secondary stress	[[kaˌfɛ]ω-ˈzĩɲu]ω	–
	[[ˌkafɛ]ω-ˈzĩɲu]ω	

In (13a) and (13b), ω marks phonological word chunks that are formed when categorizing heads send material to spell-out. Starting from the underlying root /kaˈfɛ/, which I assume to have lexically marked final stress, the morphology feeds the first chunk to phonology. For the normal suffix word, both the base and suffix are present, since the suffix is the first category head. For the special suffix word, only the base is present, since the suffix attaches outside this first spell-out domain. Stress is assigned to material that is present, and multiple primary stresses within a phonological word are resolved by subordinating all but the rightmost. Unstressed mid vowels neutralize and raise.[7] Finally, word-level secondary stress optionally applies. The derivation ends there for the normal suffix word. For the special suffix word, the first round of phonology treats the base, which does not result in any changes. The second spell-out cycle feeds the diminutive suffix *-zinho* to phonology, and the same phonological processes now apply to the entire word. Primary stress is assigned at the word level and falls on the suffix. Stress on the base from the first part of the derivation is maintained due to constraints preventing modification of stress assigned in a previous cycle (Prince 1985; Pruitt 2010). This prevents mid vowel neutralization from applying. I mark maintained base stress as secondary, but whether it subordinates to primary stress is an empirical question. The final step of word-level secondary stress is optional.

I assume that default word-level primary stress (penultimate) is assigned in most cases. Diminutives and adverbials require no extra modifications, since they have penultimate stress regardless of whether stress is lexically marked or assigned as default. In compunds, primary stress always falls on the rightmost prosodic word (Vigário 2010). Superlatives require an additional assumption: stress is always antepenultimate (*-íssimo*) and must be lexically specified. Faithfulness to lexical stress must override default stress assignment at the word level. One could also assume that all special suffixes are lexically stressed (e.g. Vigário 2003).

I depart from previous analyses that consider all special suffix words as nested prosodic word compounds. The only *necessary* component to blocking mid vowel neutralization on the base is that the base must be an independent phonological word. I consider words with diminutive/superlative suffixes to consist of an independent prosodic word base and a suffix, which combine into a larger prosodic word (14). The special suffix is not a prosodic word in and of itself. Only words with *-mente* consist of two independent prosodic words nested within a larger one, forming a prosodic compound (15).

7 While lower-mid vowel neutralization (/ɛ, ɔ/ to [e, o]) and word-final neutralization and raising (/e, o/ to [i, u]) are different processes, I use *neutralization* as a cover for both.

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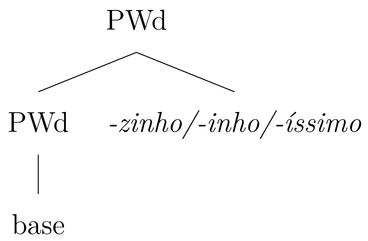
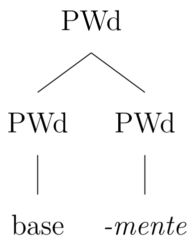
(14) Diminutives and superlatives: independent prosodic word + suffix



(15) *-mente*: nested prosodic words



Note that (14) and (15) show the final prosodic structure, without saying anything about how this structure is derived. They do not imply that the special suffix selects for a prosodic word base, but rather that this structure is the result of morphologically-determined cyclic spell-out.

3.4 ANALYSIS: ADVERBIALS

While diminutives and superlatives can be analyzed as modifiers, recall that adverbial *-mente* shares characteristics of both derivational suffixes and compounds (see Section 3.2.2). Phonologically, however, it has been analyzed as forming compound prosodic words like the other special suffixes (Section 3.1). Treating *-mente* as a root that forms a morphological compound creates the phonologically parallel behavior, despite morphological differences.

There is a long-standing debate in the literature about whether *-mente* is a derivational suffix or forms a compound. For Spanish, a compound analysis is supported by Bello (1847), Hockett (1958), Bosque (1987), Zagona (1990), and Kovacci (1999). A morphological derivation analysis is argued for in Alarcos Llorach (1970), Karlsson (1981), Miranda (1994), and Rainer (1996) (see Torner 2005 for overview of debate). For Portuguese, Rio-Torto & Ribeiro (2012) propose that *-mente* is a frontier case between derivation and compounding, and Basílio (1998) argues that is not derivational. I discuss Spanish and Italian in conjunction with Portuguese because much of the existing work focuses on these languages, and because their similarities and differences from Portuguese are informative.

For Spanish, Bosque (1987), Zagona (1990), and Kovacci (1999) argue that *-mente* forms compounds. One source of evidence is deletion (ellipsis) under coordination. *-mente* can scope over multiple feminine-inflected adjectives, appearing overtly only on the last one. In both Spanish and Portuguese, this is possible with *-mente* (16a), some prefixes (16b), and some compound structures (16c), but not with any normal suffix (16d).

(16) *Portuguese* (Vigário 2003: 251–2)

a. [segura mas lenta]-mente
sure but slow-ADV
'surely but slowly'

b. [pré e pós]-guerra
before and after-war
'pre-war and post-war'

c. [luso ou afro]-asiáticos
Luso or Afro-Asiatic
'Luso-Asiatic or Afro-Asiatic'

d. *[acampa e acantona]-mento
camp and shelter-ing
Intended: *'camping and sheltering'

However, ellipsis is not purely phonological, and thus cannot be the the only diagnostic for compound prosodic words (Vigário & Frota 2002; Vigário 2003; Guzzo 2018). If ellipsis is only allowed in phrases composed of multiple prosodic words (Guzzo 2018), then adverbials must contain multiple prosodic words. However, the same evidence cannot be used for the other special suffixes, which disallow ellipsis but are analyzed as independent prosodic words (Guzzo 2018). Ellipsis may be blocked in diminutives for semantic reasons (Vigário & Frota 2002). Containing two phonological words is necessary—but not sufficient—for ellipsis. Furthermore, some languages have similar processes where an affix scopes over a series of coordinated bases (e.g. Turkish, Kabak 2007), but this does not result in multiple prosodic words. My analysis treats *-mente* as an independent prosodic word that forms a phonological and morphological compound with its base, while the other special suffixes do not. This could explain why only *-mente* can undergo ellipsis.

Further arguments for the compound analysis of Spanish *-mente* are that it attaches to already-inflected adjectives (8). Derivational suffixes do not attach to inflected forms. It also attaches outside the superlative suffix, while normal suffixes cannot (Torner 2005). A final major argument is that *-mente* maintains stress on the base, but this argument is phonological rather than morphological. Basílio (1998) makes similar arguments for Brazilian Portuguese, focusing mostly on ellipsis under coordination and attachment to a feminine-inflected adjective.

As a counterpoint to Spanish and Brazilian Portuguese, modern Italian *-mente* is more clearly derivational (Masini & Scalise 2012). Modern Italian does not allow ellipsis under coordination—although Ancient Italian did. Masini & Scalise (2012) propose that the discrepancy between modern Italian on one hand, and Spanish and Ancient Italian on the other, may be that modern Italian *-mente* has fully grammaticalized into a derivational suffix while Spanish *-mente* has not. Spanish and Portuguese are similar with regard to distribution of *-mente*, so it is possible that the suffix is grammaticalizing in these languages (Silva et al. 2008; Duarte 2009), and that *-mente* words may still be morphological compounds.

I follow Basílio (1998) in analyzing *-mente* as a morphological compound in Brazilian Portuguese. I consider morphosyntactic compounds to consist of two roots (Harley 2009; Borer 2014). Thus, adverbials contain two independently categorized roots (√*base* + √*–mente*). Because each root is categorized, they spell out separately and receive independent stress. One reason to treat *-mente* as a root is diachronic: it derived from an independent lexical word. In most accounts, the Romance suffix *-mente* derived from Latin compounds of a feminine-inflected adjective (*lent-a* 'slow-F.SG') plus the independent noun *mens* ('mind') (Basílio 1998; Kovacci 1999; Duarte 2009; Silva et al. 2008).[8] There are also striking diachronic similarities between English adverbial *-ly* and Romance *-mente*. English *-ly* derives from Germanic NOUN-NOUN compounds composed of **-lîkom* 'appearance, body, form' (cognate of modern English *-like*) and another noun (OED 2018). For example, **mann-lîko* originally meant 'having the appearance or form of a man.' Over time, **-lîkom* reduced phonologically to *-ly* and changed from an independent noun to a bound adverbial suffix. Modern English has both *-ly* and *-like*, the latter of which is both an independent word and a suffix with relatively independent behavior. The independence of the suffix *-like* mirrors *-mente*: *-like* does not modify stress on its base (e.g. *Saskátchewan*, *Saskátchewan-like*). Other English suffixes are also argued to be compounds for similar reasons (e.g. *-type*, Dalton-Puffer & Plag 2001).

Objections to the compound analysis of *-mente* are that it is not an independent word in the language (it is bound), and *-mente* compounds are not identical to endocentric or exocentric compounds (Torner 2005). However, both of these objections are manageable. Bound roots are cross-linguistically common (*cranmorphs*, Siddiqi et al. 2014), and some affixes are treated as bound roots in languages like Halkomelem (Salish) (Wiltschko 2009), Lushootseed (Salish) (Urbanczyk 2006), and Dutch (Lowenstamm 2014; Creemers et al. 2018). While these arguments do not extend to Portuguese, the authors do draw parallels between phonological and morphological structure, as in the current study. Bound roots are not required to head their own words. Furthermore, that *-mente* compounds do not fit with other types of compounds may be expected if *-mente* is undergoing change.

The tree in (17) shows *-mente* as a root that forms morphological compounds.

8 But see Torner (2005) for a different analysis.

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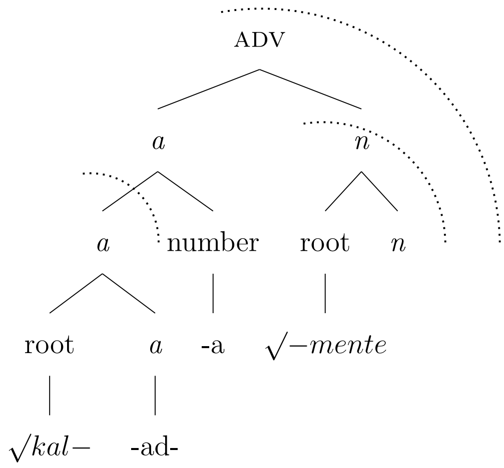
(17) Structure for *-mente* as compound (modified from Zagona 1990 for Spanish)



Each root is spelled out at its respective categorizing head, and receives stress as an independent prosodic word ([kaˈlada]$_\omega$[-ˈmẽtʃi]$_\omega$). When the two prosodic words combine into a larger prosodic word, both stresses are maintained ([[kaˈlada]$_\omega$[-ˈmẽtʃi]$_\omega$]$_\omega$). Main word stress applies to the entire word, falling on the penultimate syllable. This coincides with the stress already on the suffix ([[kaˌlada]$_\omega$[-ˈmẽtʃi]$_\omega$]$_\omega$). The leftmost stress on the base likely subordinates to main word stress somewhat, but this is an empirical question. This morphological compound structure composed of two roots differs from the modification structure for diminutives and superlatives, but the phonological result is similar. *-mente* is both a morphological and phonological compound, while diminutives and superlatives are composed of a single prosodic word (the base) plus a suffix.

3.5 ANALYSIS SUMMARY

Normal and special suffixes differ in attachment, leading to different stress patterns. The special suffixes attach to a categorized root, so that the base spells out and receives stress in a previous cycle. Normal suffixes attach to bare roots, are spelled out with the base, and receive stress as a single unit. Furthermore, diminutives and superlatives are modifiers, while adverbial *-mente* is a root itself, forming morphological compounds containing two roots. Prosodically, diminutives and superlatives consist of a suffix attached to a prosodic word base ([[base]$_\omega$-DIM/SUP]$_\omega$), while adverbials consist of nested prosodic words ([[base]$_\omega$[-mente]$_\omega$]$_\omega$). Despite this difference, the surface phonology is the same since the base is spelled out independently in both cases. The nested structure of *-mente* raises the possibility that its stress patterns differ slightly from diminutives/superlatives, and further research is needed to test this. The place and manner of attachment of the special suffixes means that the most immediate base is spelled out and stressed independently, resulting in attachment to a prosodic word; this differs from an account in which the special suffixes select for a prosodic word base.

This analysis departs from previous work that analyzes all of the special suffixes as independent prosodic words. Specifically, it differs from Bachrach & Wagner (2007) in that the special suffixes are not dominated by a categorizing head, and are therefore not independent prosodic words themselves. An analysis in which these suffixes are independent prosodic words is also possible, but the result is that diminutives and superlatives have the same compound prosodic word structure as *-mente*. This may also require that these suffixes be roots that are independently categorized.

An alternative analysis is that the special suffixes are lexically marked to subcategorize for a prosodic word base. Subcategorization analyses have been proposed for cases like Kaqchikel prefixes (Bennett 2018) and Serbian function words (Zec 2005), among others. However, as further discussed in Section 6, this kind of analysis misses important generalizations about the morphological similarities in place of attachment among the special suffixes in Brazilian Portuguese. A subcategorization approach relegates the coincidence of these morphological and phonological characteristics to chance.

4 EXPERIMENT

In this section, I first review the acoustic correlates of stress in Brazilian Portuguese and existing experimental work on special suffixes (Sections 4.1 and 4.2). Then I describe the set-up of the current experiment: data collection (Section 4.3), acoustic measurements and ratio/difference measures used in the analysis (Section 4.4), potential confounds (Section 4.5), predictions (Section 4.6), and statistical analyses (Section 4.7).

4.1 ACOUSTIC CORRELATES OF STRESS IN BRAZILIAN PORTUGUESE

Cross-linguistically, correlates of stress include duration, F0, intensity, vowel quality, and spectral tilt (Gordon 2011; Gordon & Roettger 2017). Stressed segments tend to be longer, louder, and are sometimes marked by pitch excursions. Many languages have segmental alternations in stressed syllables: stressed segments can undergo fortition or lengthening (Gordon 2011), while unstressed segments are often shorter and change quality, reducing the overall vowel inventory in these positions (Crosswhite 2004). Languages differ in which correlates they use for stress, but primary and non-primary stresses tend to be signaled by the same correlates within a language (Gordon 2011; Morrill 2011; Newlin-Lukowicz 2012).

In Brazilian Portuguese, the main correlate of primary stress is duration: stressed vowels are longer than unstressed ones (Major 1985; Massini-Cagliari 1992). F1 is also an important correlate because it reflects mid vowel height neutralization in unstressed syllables (Section 2.1). Secondary stress is thought to use correlates similar to primary stress, but experimental evidence for it is inconsistent and scant in Brazilian Portuguese and cross-linguistically. Secondary stress is relevant because, although special suffixes maintain some stress on the base, it is not clear whether it is produced with correlates of primary or secondary stress. The maintained stress may be a remnant of primary stress, but is likely subordinated to main word stress. Duration and F1 are the most robust correlates of stress in Brazilian Portuguese, but I also consider intensity because some experimental work on secondary stress finds that some speakers use it occasionally (Moraes 2003; Fernandes-Svartman et al. 2012; Ulrich 2016).

4.2 EXPERIMENTAL EVIDENCE FOR STRESS MAINTENANCE

Despite frequent assumptions that special suffix words maintain stress on the base, there is little acoustic evidence. Several production studies find evidence of stress maintenance through vowel height (F1), duration, and intensity (Quadros & Schwindt 2008; Schwindt 2013; Ulrich 2016). However, these studies are small-scale and their experimental weaknesses undermine the results.

Ulrich (2016) is the most thorough study, analyzing production data from 5 speakers (620 words total) from southern Brazil (Porto Alegre). Her target word bases contain lower-mid vowels /ɛ, ɔ/, upper-mid vowels /e, o/, and non-mid vowels, and have either special or normal suffixes. The crucial comparisons are between pretonic vowels that are stressed in the independent base and stressed vowels in the same suffixed word. For example, the base /ˈbɔla/ has the diminutive [bɔˈlĩɲa] and a normal suffix derived word [boˈlada] ('bundle, jackpot'). In the diminutive [bɔˈlĩɲa], her analysis compares [ɔ] that is stressed in the independent base to primary stressed [ĩ]. Her results show that pretonic vowels that are stressed in the independent base (and thus should maintain stress in special suffix words) are similar in length to primary stressed vowels in the same word ([ɔ] ≈ [ĩ]). In words with normal suffixes, like [boˈlada], the vowel stressed in the independent base is shorter than the primary stressed vowel of the same word ([o] < [a]). Intensity shows a less robust effect in the same direction. She interprets this as evidence of stress maintenance in special suffix words but not in normal suffix words.

Schwindt (2013) also carries out a small study of pretonic vowels in special and normal suffix words. Like Ulrich (2016), he compares the pretonic vowel that is stressed in the independent base to the primary stressed vowel in the same word. Pretonic base stressed vowels are longer and slightly louder than the primary stressed syllable in the same word (e.g. [bɔ̲ˈl-ĩ̲ɲa], [ɔ] > [ĩ]). These findings are not conclusive evidence of stress maintenance for several reasons. First, intensity is not a robust correlate of primary or secondary stress in Brazilian Portuguese. Second, initial syllables are often longer and have higher intensity simply because they are initial, and because target words are focused in formulaic carrier sentences.

The main confounding factor in Schwindt (2013) and Ulrich (2016) is vowel quality. The crucial comparisons are between vowels of different qualities, which differ inherently in duration and intensity. For American English, the average duration of /i, u/ is 16ms, while that of /a/ is 30ms, and mid vowels fall in between (Peterson & Lehiste 1960: 701). These are fairly large differences. In an example like [bɔ̠ˈl-ĩ̠ɲa] (Ulrich 2016: 114), the similar durations may not be due to stress. [ɔ] is inherently longer than [ĩ], but since [ĩ] receives primary stress, its duration could be similar to [ɔ] (stressed or unstressed). The fact that [ɔ] is *not* shorter than [ĩ]—which Ulrich interprets as stress maintenance—may be because /ɔ/ is inherently longer than [ĩ]. Another complicating factor is that *-(z)inho* has a nasalized vowel and *-mente* has a nasal vowel. Nasal vowels are longer than oral or nasalized vowels in Brazilian Portuguese (Moraes & Wetzels 1992; Medeiros 2011), so comparing them to oral vowels is problematic. Furthermore, even if pretonic [o] is shorter than primary stressed [a] in the normal suffix word [bo̲ˈla̲da], this may be because [o] is inherently shorter than [a]. In sum, it is not clear if the observed similarities and differences between pretonic base stressed and primary stressed vowels can truly be attributed to stress, or whether they are a byproduct of inherent properties of different vowels. Ulrich (2016: 113, fn. 55; 122) acknowledges these confounds, but the design does not allow her to avoid them.

The previous studies do not include vowel height as a correlate of stress maintenance; they assume that base stressed vowels maintain vowel height in special suffix words. Quadros & Schwindt (2008) address vowel height explicitly in a corpus study (36 interviews) and a production study. In the interviews, special suffix words maintain lower-mid vowels in the base at the highest rates (above 90% for all). The authors do not specify how maintenance of lower-mid vowel height was determined, and do not statistically analyze the difference in rate of low-mid vowel maintenance in special vs. normal suffix words (the difference was large). They also conducted a reading experiment, marking vowel quality impressionistically. Lower-mid vowels were maintained in more than 80% of special suffix words, but in less than 25% in normal suffix words. In sum, these studies provide initial experimental evidence for stress maintenance on the base of special suffix words. However, they use few speakers, few target words, and do not control for factors like vowel quality. They also do not analyze vowel height in reproducible way, assuming that stress maintenance through vowel height is a given.

The current production study addresses these gaps in laboratory work on Brazilian Portuguese stress to provide more thorough results. I use data from 11 speakers and 92 target words. The target words were designed in sets built off the same base, allowing a comparison of pretonic vowels in special suffix words to their counterparts in normal suffix words. This design, along with more thorough statistical methods, controls for vowel quality and other factors. The target words are also presented in naturalistic sentences, to minimize effects of initial prominence.

4.3 DATA COLLECTION

4.3.1 Participants

This study analyzes 11 native speakers of Brazilian Portuguese (8 females, 3 males), who were were recorded in New York City reading a list of sentences containing the target words, and were paid for their time. Three other speakers were recorded but are excluded from the results. One is a native English-Portuguese bilingual, and the other two come from regions that are known to neutralize unstressed mid vowels to lower-mid vowels as opposed to upper-mid vowels. Participants also filled out basic demographic questionnaires. Speakers ranged in age from 18–40. Seven participants had been in the U.S. for less than a year; four had been in the U.S. for three-five years. Their level of English proficiency ranged from basic to almost native (one speaker). All speakers had completed secondary education; nine had also completed part or all of a post-secondary program, and one had graduate-level education.

4.3.2 Procedure

Participants were recorded reading stimuli sentences in a sound booth at New York University. The recordings were done with a Marantz PMD660 recorder and an Audio-Technica ATM75 head-mounted microphone, to keep the microphone at a constant distance from the mouth. The sentences were presented in a pseudorandomized order and broken into three blocks of 50–60 sentences each. The order was consistent across participants. Before recording each block, participants were asked to familiarize themselves with the sentences. Target words were not highlighted or indicated in any way. The sentences were presented individually on a laptop screen to participants who read each sentence out loud at a comfortable pace. If they did not correct disfluent readings on their own, I asked them to repeat these sentences at the end of the block. Recording sessions were carried out entirely in Portuguese, and lasted between 15–30 minutes. Each participant read 184 sentences (92 target words × 2 sentence types per word). Sound files and textgrids are available in the Supplementary File 3.

4.3.3 Stimuli

The target words were 92 morphologically complex real words with between two and five pretonic syllables. They were created in sets by adding special and normal suffixes to the same base. The special suffixes are the diminutive *-inho, -zinho*, superlative *-íssimo* and adverbial *-mente*. The normal suffixes included suffixes like *-idade* ([ʒeneɾoz-iˈdadʒi] 'generosity'), *-tivo* ([eduka-ˈtʃiva] 'educational') and *-eza* ([delikaˈd-eza] 'delicateness'). Normal suffixes were chosen for each word set based on which ones were possible for the base, and for their ability to fit into the necessary sentence context. Building the target words off the same base allows comparisons between pretonic vowels in different word types, since the pretonic vowels are the same. Bases were selected according to several criteria. First, for sets built off bases with penultimate stress, bases had to accept several special and normal suffixes. For sets built off final and antepenultimate stress bases, the bases had to accept a minimum of one special and one normal suffix. Second, the bases had to consist mostly of light CV syllables to avoid potential effects of weight on stress (Garcia 2017). Within these constraints, I attempted to choose words speakers use regularly, but this was not always possible. The statistical analysis controls for frequency differences.

Target word sets are illustrated in (18). Of the 92 total target words, 62 had bases with penultimate stress, 18 had bases with antepenultimate stress, and 12 had bases with final stress. The 62 words built off bases with penultimate stress are divided into 16 sets of 4 words each, like (18a). Each set contains 2–3 words with special suffixes and 1–2 with normal suffixes. Sets built off antepenultimate and final stressed bases consist of two words each (18b and 18c). Each set contains one special and one normal suffix word.

(18) Example sets of target words

	Base Stress	Special Suffixes		Normal Suffixes	
a.	Penultimate	edukaˈdʒ-ĩɲa	'well behaved-DIM'	eduka-ˈtʃiva	'educational'
	Base: eduˈk-ada	edukaˈdʒ-isima	'well-behaved-SUP'		
		edukada-ˈmẽtʃi	'well-behaved-ADV'		
b.	Antepen.	mekanika-ˈmẽtʃi	'mechanical-ADV'	mekani-ˈzadu	'mechanized'
	Base: meˈkan-ika				
c.	Final	maɾakuʒa-'zĩɲu	'passionfruit-DIM'	maɾakuʒa-ˈzejɾu	'passion fruit tree'
	Base: maɾakuˈʒa				

Each word was inserted into two minimally different naturalistic sentences, representing two sentence types: immediately following a verb with (a) penultimate stress ([ˈσσ] + target word) and (b) final stress ([σˈσ] + target word). This was done to test the effect of stress clash across word boundaries. From here on, I collapse the contexts because there was no meaningful difference. Formulaic carrier phrases were avoided to mitigate effects of list reading and to draw attention away from the target words (see Appendix A, Supplementary File 1, for full list of stimuli sentences).

4.4 ACOUSTIC MEASUREMENTS

The data were analyzed using Praat (Boersma & Weenink 2018). Between 350–480 individual vowels were used from each speaker. One target word set (base: [amaˈɾɛla]) was excluded from all of the data because many speakers had difficulty with the target words. ***Table 1*** shows the number of vowels and ratios analyzed in the models. These numbers reflect data excluded due to reading disfluencies involving the target word or the immediately surrounding context, as well as unmeasurable vowels.

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		INDIVIDUAL VOWELS		DURATION RATIOS/DIFFERENCES	
BASE STRESSED	VOWEL	UR (BASE)	#	UR (BASE)	#
No	[a]		1099		435
	[e]		717		404
	[i]		934		482
	[o]		475		340
	[u]		121		71
Yes	[a]		940		631
	[e]	/ɛ/	43	—	—
	[ɛ]	/ɛ/	43	/ɛ/	74
	[i]		233		111
	[o]	/ɔ/	39	—	—
	[ɔ]	/ɔ/	63	/ɔ/	53
	[u]		79		35

Table 1 Total individual vowels (outliers not removed) and special:normal ratio measures for Duration (outliers removed).

The left side of ***Table 1*** shows the total number of vowels analyzed in all words (special and normal, stressed and unstressed in the base), broken down by vowel quality. Some outliers were later removed (see Section 4.7 for details on outliers). The underlying vowel column specifies the underlying vowel quality in the base for mid vowel pairs that are said to differ allophonically, like [kafɛ-ˈzĩɲu]: [kafe-ˈtejɾa] (UR /ɛ/). For base stressed vowels, [e, o] surface as forms of base stressed /ɛ, ɔ/ in normal suffix words, while [ɛ, ɔ] surface as forms of base stressed /ɛ, ɔ/ in special suffix words. The statistical models on raw measurements contain only the base stressed vowels.

The right side of ***Table 1*** shows the approximate number of special:normal ratios analyzed per correlate, with outliers removed (see Section 4.7 for details on outliers). The specific numbers in this table are for Duration. All stressed base /ɛ, ɔ/ surface as [ɛ, ɔ]. The ratios reported are special:normal ratios or differences, so base stressed /ɛ, ɔ/ are maintained in special suffix words and are treated as such in the analysis. The ratio/difference models include both underlyingly stressed and unstressed vowel ratios.

The verbs and target words were segmented and coded manually by the author and four undergraduate research assistants. Strict segmenting criteria were established. We segmented the pretonic and primary stressed vowels in each target word, as well as the final vowel of the preceding verb. Primary stressed vowels of the target words and final vowels of the preceding verbs were marked but not segmented carefully, because they fall outside the analysis. Each vowel was labeled for expected vowel quality, position in relation to main stress, and sentence type. Segmentation was done with the waveform and spectrogram, using the zero-crossings of the onset and offset of F2 to mark vowel edges. The beginnings of vowel-initial target words were marked at the onset of F2, but were often difficult to determine. Preceding verbs necessarily end in vowels and the boundary is often unclear ([kãta animadaˈmẽtʃi], *canta animadamente* 'sings excitedly'). When there was no clear acoustic distinction between adjacent vowels, these vowels were excluded. When they could be distinguished by abrupt changes in formant structure and intensity (e.g. because there was a glottal stop or glide), the beginning of the target word was marked at the intensity increase after low intensity of the glottal stop or glide.

Nasal and rhotic codas were segmented as part of the vowel, and the entire rime was analyzed (vowel + nasal/rhotic). Nasal vowels are assumed to be followed by an underlying nasal coda (Câmara 1970a; Mateus & d'Andrade 2000; Bisol & Veloso 2016; see Medeiros 2011 for experimental evidence). For example, regardless of whether *generosamente* was produced as [ʒeneɾɔza-ˈmẽtʃi] or [ʒeneɾɔza-ˈmẽntʃi], the syllable [ẽn] ~ [ẽ] was segmented as a unit. Coda rhotics were segmented in the same way since they are realized as taps, fricatives or retroflexes [h, ɦ, ɾ, ɹ] depending on the dialect (Cristófaro Silva 1998; Cardoso et al. 2014). Including them with the vowel was the only way to maintain consistency within and across speakers. Because the ratio comparisons are within-speaker across different members of a single target word set, a syllable with a coda rhotic (*modernamente*, [modɛɾna-ˈmẽtʃi] 'modern-ADJ') is always compared to the same syllable in a different form of the word produced by the same speaker (*modernidade* [modeɾni-ˈdadʒi] 'modernity'). Only the relative difference between the two for a given speaker matters.

A supporting analysis with raw measurements treats each individual vowel as a token, and excludes word sets whose base contains coda rhotics, nasals, and nasal vowels. Including target word sets with codas would mean comparing vowels in syllables with and without codas. Vowels in open and closed syllables differ inherently in length, which could obscure the comparison of interest between base vowels that do and do not show base stress maintenance.

For each vowel, duration, maximum intensity, and F1 (at the midpoint) were extracted via Praat script. The raw extracted data is available in the Supplementary File 2.

4.4.1 Ratios and difference Measures

The main analysis is on ratio and difference measures for Duration, Intensity, and F1 (vowel height). Using ratios and difference measures mitigates inevitable confounds by comparing a vowel in one target word to the same vowel in another target word with the same base. Perfectly balanced stimuli are impossible, since vowel distribution is uneven across position (in relation to main stress) and level of stress (stressed, unstressed) in real words. Vowels differ inherently in duration and intensity and would contribute differently to overall measurements (see Section 4.2). Duration ratios have been previously used in comparing stressed and unstressed vowels (Delattre 1966). I use a difference measure instead of a ratio for F1.[9]

The ratio analysis compares each vowel in a special suffix word to its counterpart in a normal suffix word using ratios (for duration and intensity) and difference measures (for F1). I illustrate with a single word set: *educadinha* (DIM), *educadíssima* (SUP), *educadamente* (ADV), *educativa* (normal). Every pretonic vowel in the special suffix words is compared to the corresponding vowel in the normal suffix word *educativa*. As shown in (19) /e/, /u/ and /a/ in the special suffix word [edukaˈdʒĩɲa] are compared to /e/, /u/ and /a/ in the normal suffix word [edukaˈtʃiva]. For each pretonic vowel in a special suffix word, there is one ratio per correlate. In the set built off *educada*, there are three Duration ratios, three Intensity ratios, and three F1 differences. Some word sets contained multiple normal suffix words. In these cases, each vowel in the special suffix words was compared to the average of its duration/intensity/F1 in the normal suffix words. Ratios above one indicate a longer/louder vowel in the special suffix word than in the normal suffix word, suggesting stress maintenance.

(19) Sample special:normal duration ratio calculation for speaker M3

	Word	e	u	a
Special	[edukaˈdʒĩɲa]	55ms	33ms	55ms
Normal	[edukaˈtʃiva]	54ms	29ms	34ms
Ratio		1.02	1.14	1.61

(20) Sample F1 absolute difference calculations for speaker M3

	Word	a	e
Special	[kafɛˈzĩɲu]	684Hz	505Hz
Normal	[kafeˈtejɾa]	670Hz	411Hz
F1 diff.		14Hz	94Hz

Vowel reduction is measured through the magnitude of the absolute difference in F1 for the same vowel in two different words in the same set, as illustrated in (20). The absolute magnitude of the difference indicates how much the vowel changes in quality between the

9 One could also use a ratio measure for F1, although it is not clear why one would be better than the other. F1/F2 ratios have been used in calculating differences in vowel space and centralization (Audibert & Fougeron 2012; Nadeu 2014; Romanelli et al. 2018), but it is not clear that capturing overall vowel space through ratios that take into account multiple dimensions is useful for single-dimension F1 measurements.

special and normal suffix words. This correlate is expected to be strongest for mid vowels, for which reduction in unstressed syllables is considered allophonic (see Section 2.2.2). Mid vowels that are stressed in the independent base should maintain vowel quality in special suffix words as compared to normal suffix words, since they supposedly maintain stress in the former but not the latter. For example, a lower-mid vowel that is stressed in the base ([kaˈfɛ]) should maintain this vowel quality in special suffix words ([kafɛˈzĩɲu]) (higher F1). In normal suffix words, it should lose stress and raise ([kafeˈtejɾa]) (lower F1). Larger absolute difference measures indicate reduction via raising; smaller absolute difference measures indicate similar vowel qualities, and thus stress maintenance.

4.5 CONFOUNDS

Working with real words means there are confounds in experiment design and in measuring base stress realization. The most important include number of vowels, clash, vowel position, stress profile of the base, and type of special suffix. These predictors are included in the statistical models in order to control for their effects.

Number of vowels and vowel position: Differences in word length could plausibly affect the ratios because of compression in longer words. It was not possible to always have the same number of vowels in the special and normal suffix word, because special suffixes are 2–3 syllables long and differ in whether the theme vowel of the base deletes. Both *-inho* and *-mente* have 2 syllables, but *-mente* words are longer than *-inho* words built off the same base. This is because the theme vowel is deleted in *-inho* words ([kalaˈdʒ-ĩɲa], 4 syllables) but not in *-mente* words ([kalada-ˈmẽtʃi], 5 syllables). Superlatives are also longer than *-inho* diminutives, because the suffix is longer ([kalaˈdʒ-ĩɲa], 4 syllables) vs. [kalaˈdʒ-isima], 5 syllables). While the target words were chosen to control for word length as much as possible, a vowel in an *-íssimo* or *-mente* word may actually come from a word with more syllables than its counterpart in a normal suffix word. However, if word length did affect the comparisons, it would work against the results of the current experiment. If the normal suffix word has *fewer* syllables than the special suffix word, then vowels from the normal suffix words could be longer simply because the word has fewer syllables. This would lead to *lower* ratios, undermining effects of stress maintenance on the base. Unlike using raw measurements, the ratio design makes the effects of stress maintenance visible regardless of word length.

Clash: Stress retraction due to clash could also introduce confounds. Section 2.2 describes clash in Brazilian Portuguese. Here, I only reiterate that *-inho* and *-íssimo* frequently cause clash ([kaˈlada], [kaˌlaˈdʒísima], [kaˌ ʒu ˈzĩɲu]). *-zinho* can also cause clash when it attaches to a final-stress base ([kaˈʒu], [kaˌʒuaĩɲu]. If stress retraction is at work in these words, it would weaken visible effects of stress maintenance on the base. Stress retraction to a preceding syllable would make the base stressed vowel shorter and quieter, making it more similar to its normal suffix word counterpart, and lowering the ratio closer to 1.

Stress profile of the base and type of special suffix: The special suffixes can attach to bases with different stress profiles. See Section 2.2 for information on which special suffixes attach to bases of which shape. In my experiment, not all special suffixes attach to all possible bases. To maintain consistent numbers of words in the sets, I had to limit the stimuli in the following way. Penultimate stress bases occur with *-inho, -mente, -issimo*. Antepenultimate stress bases occur with *-mente* or *-zinho*, and final stress bases occur with *-zinho*. No other combinations exist in the target words.

4.6 PREDICTIONS

If there is stress maintenance on the base of special suffix words, vowels that are stressed in the independent base should be acoustically different in special suffix and normal suffix words, leading to high ratios and difference measures. Unstressed base vowels should be similar in both word types. Therefore, ratios and difference measures should be higher for stressed base vowels than for unstressed base vowels. Mid vowels may show larger effects than high and low vowels, since they reduce allophonically when unstressed. The models test stress maintenance by comparing stressed base vowel ratios to unstressed base vowel ratios. Evidence of stress maintenance on the base would include a significant effect of being stressed in the base, with a possible interaction with vowel quality. Specific predictions are as follows:

- **Duration:** Vowels that are stressed in the independent base should be longer in special suffix words than in normal suffix words (ratio > 1). Unstressed base vowels should be approximately the same length in both word types (ratio ≈ 1), so stressed base vowels should have higher ratios than unstressed base vowels. Duration is expected to show this effect, since it is the main correlate of primary stress.
- **Intensity:** Intensity is, at best, an inconsistent correlate of stress in Brazilian Portuguese. If there is any effect, stressed base vowels should be louder in special suffix words than in normal suffix words. Unstressed base vowels should be approximately the same intensity in both word types. As for duration, the ratios should be higher for stressed than for unstressed base vowels.
- **Vowel height (F1):** Stressed base mid vowels (/e, o, ɛ, ɔ/) should differ in height (F1) between special and normal suffix words. Unstressed base mid vowels should be similar in both word types, since they are unstressed in both. Absolute difference measures should be greater for mid vowels that are stressed in the base as compared to those that are unstressed in the base. Low and high base stressed vowels may differ somewhat in height, but the effect is likely smaller than for mid vowels.

4.7 STATISTICAL ANALYSES

Linear mixed-effects regressions were run using the *lme4* package (Bates et al. 2015) in R (R Core Team 2020), with the *bobyqa* optimizer. P-values were obtained using the *lmerTest* package (Kuznetsova et al. 2017).

After data extraction, outliers were dealt with in several ways: the first round caught measurement errors from Praat, and the second excluded true outliers. First, I calculated z-scores for all individual data points for Intensity and F1 (by speaker and by vowel). I hand-checked tokens with measurements more than 3 standard deviations away from the speaker's mean for that vowel quality. Only F1 measurements that were off by over 75Hz and Intensity measurements that were off by over 1dB were manually corrected. I did not change measurements that differed from the automatically extracted ones by less than these amounts. In two cases, Praat extracted F1 measurements of over 1000Hz; these were clearly measurement errors, but measuring by hand gave the same result. These tokens were excluded. A total of 8 Intensity measurements and 25 F1 measurements were changed manually.

Then, I excluded outliers from the raw measurement and ratio/difference data sets. In the raw measurement data set, the z-score was calculated for each data point. As before, data points falling more than three standard deviations away from the speaker's mean for the given vowel category were considered outliers. A total of 82 individual vowel outliers were removed. Of those, øø were removed from the set of stressed base vowels that was used in the models (11 for Duration; 7 for Intensity, 4 for F1). For F1, outliers were removed after vowel normalization (Section 4.7.2).

For the ratio/difference data, outliers were defined as data points falling more than three standard deviations above or below the *overall* mean. Ratios/differences already control for speaker-specific differences. A total of 40 outliers were removed for Duration, 30 for Intensity, and 66 for F1.

4.7.1 Ratio/Difference Models

Separate models were built for duration ratios, intensity ratios, and absolute magnitude of F1 differences. Superset models for each correlate contained the fixed effects and interactions in (21), as well as random intercepts for base and speaker, and a random slope of vowel height by speaker. Further random slopes by speaker were not included because some models did not converge with them. For consistency, I included the only random slope with which all models converged.

(21) Fixed effect predictors considered for all models (levels of each predictor are in parentheses)

- **Frame:** target word preceded by word with penultimate stress (1) or final stress (2) (1, 2)
- **Number of syllables:** target words have between 4–7 syllables (4, 5, 6, 7)
- **Position of vowel:** position of the given pretonic vowel from beginning of the word (Ordinal, 1–5)
- **Vowel height:** height of vowel (high /i, u/, mid /e, o, ɛ, ɔ/, low /a/)
- **Stressed in base:** if the given vowel receives stress in the independent base (True, False)
- **Distance from primary stress:** the position of the given vowel in relation to main stress in the special suffix word (clash, no clash, 1, 2, 3, 4). *Clash* means immediately adjacent to primary stress in the special suffix word, and stressed in the base (e.g. /kaˈʒu/, [kaˌʒu̲-ˈzĩɲu] 'cashew-DIM'). *No clash* means immediately adjacent to primary stress in the special suffix word, but *not* stressed in the base (e.g. /pAˈsifika/, [paˌsifika̲-mẽtʃi] 'peaceful-ADV').
- **Stress profile of base:** location of stress on the base word (penultimate, final, antepenultimate)
- **Log frequency (base):** log frequency of the base word (Continuous)
- **Log frequency (derived word):** log frequency of the special suffix word in the ratio (in ratio models), or of the (suffixed) target word in the raw measurement models (Continuous)

Frequency data comes from the Web/Dialects section of the BYU Corpus do Português, which contains 1 billion words from web pages (Davies & Ferreira 2006).[10] Searches were done by lemma for words per million. Two frequencies were calculated for each target word: (1) the frequency (per million) of the set base (e.g. *café*); (2) the frequency (per million) of the derivative special suffix word (e.g. *cafezinho*). Frequency of the special:normal ratio is the frequency of the special suffix word only. Words absent from the corpus were given a frequency of 0.000001. From here, log frequency was calculated. Word and base frequency were both included, because previous work finds a relationship between frequency of the embedded (*café*) and embedding (*cafezinho*) words. Embedding words are less likely to preserve the stress pattern of the embedded word when the former are more frequent than the latter (Collie 2008). Following Collie (2008), I considered embedded and embedding frequencies (and their interaction) as independent predictors in the models.[11]

Based on the superset models, the final models were constructed through step-down model comparison using the *step()* function from the *lmerTest* package (Kuznetsova et al. 2017). This function removes non-significant fixed effects based on *F*-tests to arrive at a reduced model (Kuznetsova et al. 2017). I manually set the threshold to $\alpha = .1$, preferring to include potentially relevant fixed effects than accidentally exclude them. The random effects were not considered for exclusion, since they are justified by the predictions and experiment design.

The models include all measurable special:normal ratios calculated for each correlate (except outliers), and compare the ratios of stressed base vowels to the ratios of unstressed base

10 *HTTPS://WWW.CORPUSDOPORTUGUES.ORG/WEB-DIAL/.*

11 One could imagine that the two frequency types interact with vowel quality, since acoustic correlates of stress maintenance are strongest for mid vowels. I ran models including this 3-way interaction, and, indeed, there is a significant interaction between base frequency, word frequency, and vowel height. In the duration model, the three-way interaction is only significant for mid vowels; in the F1 difference model, it is only significant for low vowels. The Likelihood Ratio Test (LRT) (with the *anova()* function in R) compares the likelihood of the data given each model and performs a test indicating whether the data is significantly more probable under one model than the other. LRTs on these models indicate that the model with the 3-way interaction improves model fit significantly for both Duration and F1. However, this interaction is difficult to interpret, does not change the direction or significance of the effects crucial to the main point, and a thorough examination of frequency effects falls outside the scope of this paper. All reported models include only the two-way interaction between the types of frequency.

vowels. To illustrate, the set *educadinha, educadíssima, educadamente, educativa* produces a maximum of 9 ratios for each correlate, since three special suffix words have three pretonic vowels each. The models excluded normal:normal ratios, which only occurred in the few word sets with multiple normal suffix words. The ratios of unstressed base vowels hover around 1 (unstressed in both the special and normal suffix word). A positive significant effect of the predictor Stressed in Base means a larger ratio/difference and thus a larger difference between a vowel in a special vs. normal suffix word. This suggests stress maintenance in special suffix words as compared to normal suffix words.

I modeled log-transformed ratios/differences for duration and F1, and untransformed ratios for intensity. Linear models assume normally-distributed errors and equal variance (Gelman & Hill 2006). The residuals for untransformed duration and F1 data showed skewness (both measures) and unequal variance (heteroscedasticity, F1 differences only). Log-transformed duration and F1 data improved the distribution of residuals and variance. Model fit was better, as indicated by lower values for the Akaike Information Criterion (AIC) (a measure of how well the model fits the data) (Sakamoto et al. 1986). Intensity was not transformed because the residuals were normally distributed and log transformation worsened model fit. I relied on AIC alone to assess model fit because models with different dependent variables (untransformed and transformed data) cannot be compared statistically using the Likelihood Ratio Test (LRT). LRTs compare the probability of the data given each model, but can only be run on nested models where one model has a subset of the predictors of the other (Pinheiro & Bates 2000).

Table 2 shows the predictors considered for each superset ratio/difference model (duration, intensity, F1), and those that remained in the models after step-wise predictor selection. Because fully-crossed models with all possible interactions did not converge, I selected the most plausible interactions given the design and predictions from previous studies. Specifically, the interaction between Frame and Vowel Position is important because of possible stress clash between the final vowel of the verb and first vowel of the target word. Base and Word Frequency might interact as per Collie's (2008) work. Finally, Stressed in Base and Vowel Height would interact if acoustic evidence of stress maintenance is stronger for some vowel qualities than others. This interaction turns out to be crucial: stress maintenance shows up robustly for mid vowels, and more weakly for low and high vowels.

DURATION (LOG), INTENSITY	
Simple	frame + **number of syllables** + **vowel position (from beginning)** + **vowel height** + **stressed in base** + freq-word + freq-base + **distance from primary** + base stress profile
Interactions	frame*vowel position (from beginning) + **stressed in base*vowel height** + freq-word*freq-base
Random effects	**(1 | base) + (1 + vowel height | speaker)**
F1 Differences (log)	
Simple	frame + number of syllables + **vowel position (from beginning)** + **vowel height** + **stressed in base** + freq-word + **freq-base** + distance from primary + base stress profile
Interactions	frame*vowel position (from beginning) + **stressed in base*vowel height** + freq-word*freq-base
Random effects	**(1 | base) + (1 + vowel height | speaker)**

Table 2 Predictors considered for each model. Predictors that remain after step-wise predictor selection are in bold (Duration, F1) and underlined (Intensity).

4.7.2 Raw measurement models

A secondary analysis on raw duration, intensity, and F1 measurements contains a subset of the possible predictors in (21).[12] These models were run only on stressed base vowels in order to compare stressed base vowels in normal and special suffix words directly. The F1 model for mid vowels (/ɛ, ɔ/) contains both vowels that surface as [ɛ, ɔ], and those that typically surface as [e, o] (e.g. /kaˈfɛ/, [kafeˈtejɾa]). Vowel measurements were normalized by speaker using the Lobanov method, calculated using the *vowels* package (Kendall & Thomas 2018) in R.

12 For example, the raw Duration and Intensity models consisted of the following predictors: frame, number of syllables, vowel position, vowel, suffix type, stressed in base, distance from primary, base stress profile, interactions of vowel*suffix type and freq-word*freq-base, and random intercepts for base and speaker. The F1 models were similar, but did not include vowel since separate F1 models were run for each vowel height.

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The same main results hold in the raw measurement data, but this method is built on the methodological weaknesses of previous work by comparing inherently different vowels and conflating these differences with stress. I include them as a sanity check and for the purposes of comparison with previous work.

Table 3 shows the number of individual measurements (single vowels) in the raw duration, intensity, and F1 models (separated by vowel height), and the number of measurements in each ratio/difference model (excluding problematic word sets, speaker errors, and outliers).

	RAW MEASUREMENT MODELS (VOWELS STRESSED IN BASE ONLY)	RATIO MODELS (SPECIAL:NORMAL RATIOS)
Duration	1429	2636
Intensity	1433	2648
F1	–	2610
F1 /a/	759	–
F1 /ɛ, ɔ/	152	–
F1 /i/	190	–
F1 /u/	65	–

Table 3 Number of measurements used in the models.

5 RESULTS

5.1 DURATION

Figure 1 shows that vowels that are stressed in the base have higher special:normal ratios than those that are unstressed in the base. For example, the ratio for stressed base [ɛ] in [kafɛ̲ˈzĩɲu]:[kafe̲ˈtejɾa] (Base: /kaˈfɛ/) is larger than that of unstressed base [o] in [mo̲dɛɾnaˈmẽtʃi]:[mo̲dɛɾniˈdadʒi] (Base: /moˈdɛɾna/). Put differently, stressed base vowels are longer in special suffix words than in normal suffix words, while unstressed base vowels are approximately the same length in both types of words. The effect is larger for mid vowels than for high and low vowels. Base stressed mid vowels differ substantially in special and normal suffix words (leading to high ratios); base stressed low and high vowels are more similar in the word types (leading to lower ratios). Individual speakers vary, but all go in the same direction (see Appendix B, Supplementary File 1, for individual results).

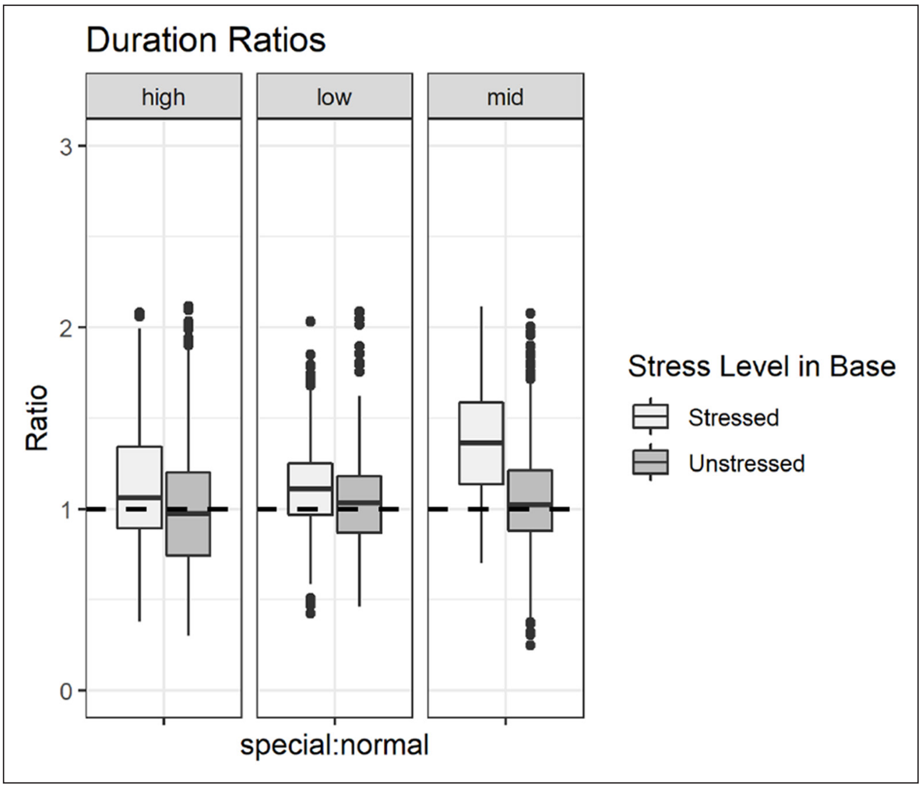

Figure 1 Duration ratio results for special suffix words (represented by special:normal ratios).

The final duration model (***Table 4***) confirms these observations. In special:normal ratios, there is a significant main effect of Stressed in Base, and a significant interaction between Stressed in Base and Vowel Height. Vowels that are stressed in the base have higher ratios than those that are unstressed in the base ($\beta = .11$, $p < .01$). The significant interaction with vowel height indicates that the effect of being stressed in the base is stronger for mid vowels ($\beta = .09$, $p < .05$). While there is a main effect of being stressed in the base, mid vowels drive the effect and low/high vowels show much weaker effects. Duration may reflect actual surface stress for all vowels. However, since the effect is driven by mid vowels, it could also be a byproduct of the allophonic differences between [e, o] and [ɛ, ɔ].

	ESTIMATE	STD. ERROR	DF	T VALUE	PR (> /T/)	
(Intercept)	–0.066	0.074	48.977	–0.889	0.379	
Number of syllables	0.039	0.014	54.759	2.679	0.010	**
Vowel position from beginning 2	–0.048	0.019	1039.451	–2.482	0.013	*
Vowel position from beginning 3	–0.091	0.031	455.497	–2.918	0.004	**
Vowel position from beginning 4	–0.163	0.047	406.360	–3.437	0.001	***
Vowel height low	0.065	0.026	35.686	2.509	0.017	*
Vowel height mid	0.094	0.022	49.203	4.320	0.000	***
Stressed in base TRUE	0.105	0.032	1152.718	3.298	0.001	**
Vowel position from primary No Clash	–0.134	0.081	964.626	–1.654	0.099	.
Vowel position from primary 1	–0.148	0.019	2460.939	–7.756	0.000	***
Vowel position from primary 2	–0.181	0.025	1119.843	–7.288	0.000	***
Vowel position from primary 3	–0.221	0.034	740.999	–6.457	0.000	***
Vowel position from primary 4	–0.264	0.051	769.366	–5.155	0.000	***
Vowel height low:Stressed in base TRUE	–0.068	0.037	913.665	–1.854	0.064	.
Vowel height mid:Stressed in base TRUE	0.088	0.042	1214.213	2.102	0.036	*

Table 4 Duration ratio model (log).

There are also significant main effects of Vowel Position (from the beginning of the word) and Distance from Primary Stress (moving backwards from primary stress). Because these are effects on ratios, however, they are not very informative. Counting from the beginning of the word, the second, third and fourth vowels ([pozitʃiva-mẽtʃi]) all have smaller ratios than the vowel in the initial syllable ([pozitʃiva-mẽtʃi]) (2nd position: $\beta = -.05$, $p < .05$; 3rd position: $\beta = -.09$, $p < .01$; 4th position: $\beta = -.16$, $p < .01$). These vowels are not necessarily *shorter* than the first vowel; they are more similar in special and normal suffix words than initial vowels are. In terms of clash, recall that vowels in clash position are stressed in the base and adjacent to primary stress in the derived word ([kaˈfɛ], [kaˌfɛˈzĩɲu]). Moving backwards from primary stress, vowels in clash position have *higher* ratios than those one vowel away ($\beta = -.15$, $p < .001$), two vowels away ($\beta = -.18$, $p < .001$), three vowels away ($\beta = -.22$, $p < .001$), and four vowels away ($\beta = -.26$, $p < .001$). The negative estimates indicate that ratios are lower for vowels further away from primary stress than for vowels in clash position. Vowels adjacent to primary stress that are *not* stressed in the base do not cause clash ([paˈsifika], [paˌsifikamẽtʃi]). Their ratios do not differ significantly from those that create clash ($\beta = -.13$, $p = .10$). Clash could cause retraction in cases like [kafɛˈzĩɲu] → [kafɛˈzĩɲu], such that /a/ lengthens and /ɛ/ shortens. This would increase the ratio of /a/ and decrease the ratio of /ɛ/, since the retraction does not occur in the normal word comparison. In short, vowels do not shorten to alleviate clash in special suffix words. The data provide no evidence for retraction, but the stimuli were not designed for this purpose and the results should be taken as merely suggestive.

The raw duration model (on stressed base vowels only) shows similar results (model not reported). There is a main effect of Suffix Type: base stressed vowels are longer in special suffix words than in normal suffix words ($\beta = .01$, $p < .001$). A significant interaction between Suffix Type and Vowel indicates that the effect is strongest for mid vowels (/ɛ/: $\beta = .04$, $p < .001$;

/ɔ/: $\beta = .02$, $p < .001$), and significantly weaker for /i u/ (/i/: $\beta = -.009$, $p < .001$; /u/: $\beta = -.008$, $p < .05$). Vowels are also shorter in longer words ($\beta = -.007$, $p < .001$), which is expected because of compression. While the duration ratio model predicts larger ratios in longer words, this effect is small. Furthermore, larger ratios in longer words does not mean *vowels* are longer in longer words. Instead, in a given word pair (*positivamente, positividade*), the difference between a vowel in a special and normal suffix word is greater than that same difference in a shorter word set (*cafezinho, cafeteira*). It is not surprising that compression effects are absent, since the ratios control for word length by comparing vowels in words of (mostly) equal length. Finally, vowels in clash position are *longer* than those not adjacent to primary stress. In comparison to stressed base vowels immediately adjacent to primary stress, vowels one and two positions away from primary stress are shorter ($\beta = -.01$, $p < .001$, and $\beta = -.04$, $p < .001$, respectively). This replicates previous findings that vowels immediately adjacent to primary stress are longer than those earlier in the word (Gama Rossi 1998; Arantes & Barbosa 2002). These results are the same as the ratio model: clash is not resolved by shortening. Crucially, the effect of base stress holds despite the potential for clash resolution, which would, if anything, undermine the results.

The duration differences between base stressed mid vowels in special suffix words and their counterparts in normal suffix words are likely perceptible, but it is not clear that the differences for other vowels are. ***Figure 2*** plots the duration of stressed base vowels in special and normal suffix words: all vowels are longer in special than in normal suffix words, but the effect is small for all but the mid vowels. The JND (just noticeable difference) for English vowel duration is around 20–25ms (Huggins 1972; Klatt & Cooper 1975; Klatt 1976). In the current study, the difference in duration between vowels in special and normal suffix words is over the JND only for /ɛ, ɔ/ (35–36ms longer in special suffix words than in normal suffix words) (***Table 2***). The raw measurement data modeled lacks /e, o/, since no target words have underlying stressed /e, o/. For base stressed /a, i, u/, the duration differences between normal and special suffix words fall well below the threshold.

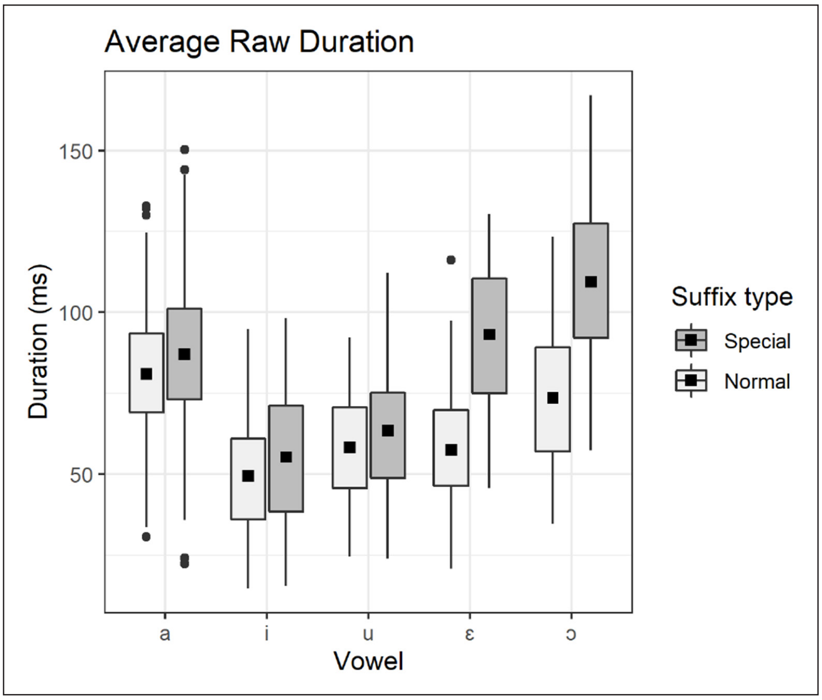

Figure 2 Raw duration by vowel in special and normal suffix words (stressed base vowels only).

Table 5 also highlights differences in inherent vowel duration and the potential confounds of comparing vowels of different qualities. Regardless of whether /i/ is stressed or unstressed, it is always shorter than stressed or unstressed /a/. These inherent differences make comparisons like those in studies discussed in Section 4.2 problematic.

In sum, duration suggests stress maintenance on the base: vowels that are stressed in the independent base are longer in special suffix words than in normal suffix words, reflecting stress maintenance in the former. The effect is strongest for mid vowels, which reduce the most when unstressed (Section 2.1). The effects for /a, i, u/ are smaller in magnitude and

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VOWEL	DUR: NORMAL	DUR: SPECIAL	DIFFERENCE
i	49	55	6
u	58	63	5
a	81	87	6
ɔ	74	109	35
ɛ	57	93	36

Table 5 Average duration (ms) for stressed base vowels in special and normal suffix words.

potentially imperceptible. If the duration effect holds robustly only for mid vowels, this could indicate stress at a point in the derivation when mid vowel reduction takes place, rather than surface stress.

5.2 INTENSITY

Figure 3 shows special:normal intensity ratios for vowels that are stressed and unstressed in the base, which hover around 1 for all vowels.

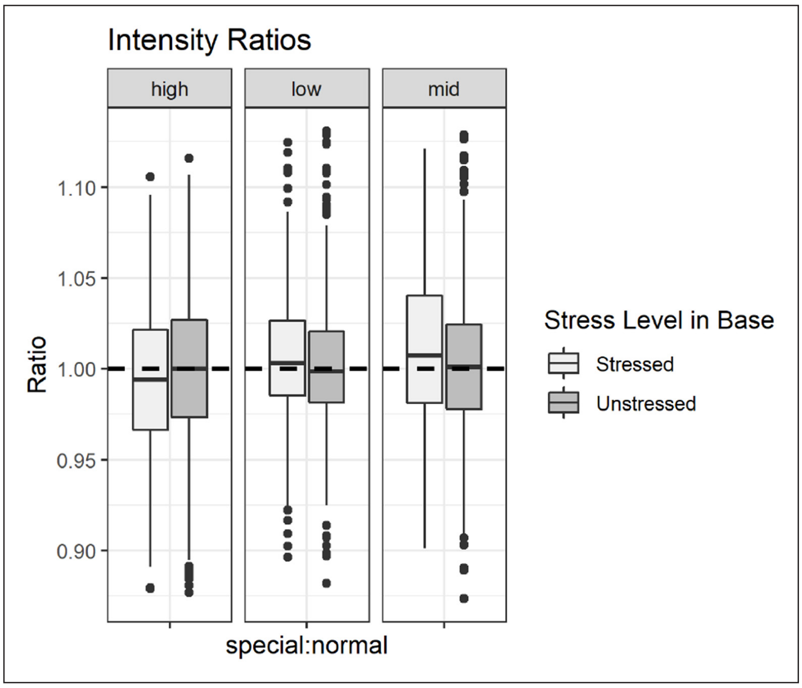

Figure 3 Intensity ratio results for special suffix words (represented by special:normal ratios).

The final model (***Table 6***), however, has a marginally significant effect of Stressed in Base in the expected direction. Vowels that are stressed in the base have significantly higher intensity ratios than those that are unstressed in the base (β = .003, p =.05). For example, in the base [eduˈkada], the penultimate vowel is stressed. This vowel is louder in the special suffix word [edukaˈdʒĩɲa] than in the normal suffix word [edukaˈtʃiva]. In contrast, the unstressed /u/ in the base [eduˈkada] is approximately the same intensity in the special suffix word [edukaˈdʒĩɲa] and in the normal suffix word [edukaˈtʃiva]. Intensity is not a robust correlate of stress in Brazilian Portuguese, but increased intensity would, if anything, reflect stress maintenance. The model of raw intensity shows the same results: stressed base vowels in special suffix words are louder than those in normal suffix words (β = .82, p < .001), and this effect is weakest for the high vowels.

The effects are significant, but small and potentially imperceptible. Flanagan (1955) reports the minimum JND for intensity at 1.2dB. In my study, the differences between stressed base

	ESTIMATE	STD. ERROR	DF	T VALUE	PR (> |T|)
(Intercept)	1.001	0.002	26.815	426.804	0.000
Stressed in base TRUE	0.003	0.002	357.201	1.947	0.052

Table 6 Intensity ratio model.

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vowels that maintain stress and those that lose it fall well below the JND (*Table 7*). However, regardless of perceptibility, the realization is consistent and correlated with base stress. Intensity potentially provides phonetic evidence of stress maintenance on all vowels, and the effect size does not differ significantly by vowel quality.

STRESSED IN BASE?	INTENSITY (DB): NORMAL	INTENSITY (DB): SPECIAL	DIFFERENCE (DB)
Unstressed	70.55	71.03	0.48
Stressed	70.72	71.27	0.55

Table 7 Average raw intensity (dB) for normal and special suffix words and absolute difference.

5.3 VOWEL HEIGHT (F1)

Recall that large F1 differences indicate that two instances of the same vowel differ in height ([kafɛ̲ˈzĩɲu]: [kafe̲ˈtejɾa]); small differences indicate that the vowels are close to the same height ([pozitʃi̲vaˈmẽtʃi]: [pozitʃi̲viˈdadʒi]). The measure is the *absolute difference in magnitude* between two measurements of F1. All speakers who reduced did so by raising (see Appendix B, Supplementary File 1, for individual results).

Figure 4 plots F1 difference measures by vowel height. Mid vowels that are stressed in the base (/ɛ, ɔ/) have high difference measures, reflecting large differences between height in special and normal suffix words. Unstressed base mid vowels /e, o/ (all upper-mid, since unstressed base vowels cannot be lower-mid), have smaller difference measures, indicating similar height in both word types. For high and low vowels, however, the difference in height between special and normal suffix words does not depend on if the vowel is stressed in the independent base or not. To illustrate, the difference in height between *stressed* base /i/ in the special word [pozitʃi̲vaˈmẽtʃi] and in the normal suffix word [pozitʃi̲viˈdadʒi] is equal to the difference between *unstressed* base /i/ in [pozi̲tʃivaˈmẽtʃi] and in [pozi̲tʃiviˈdadʒi].

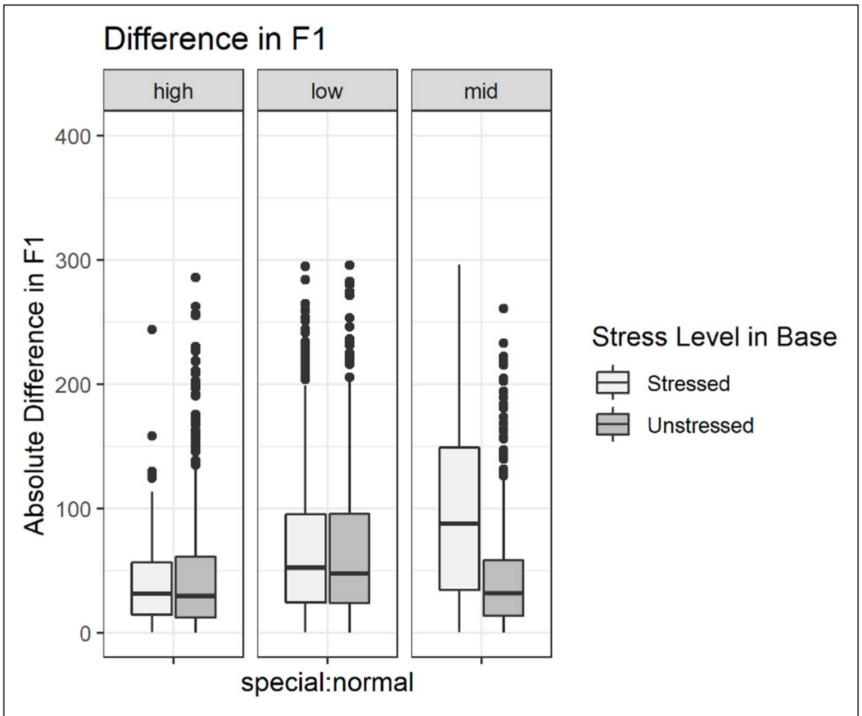

Figure 4 F1 difference results for special suffix words.

The final model for F1 differences (*Table 8*) has a significant main effect of Vowel Height and a significant interaction between Vowel Height and Stressed in Base. I limit the discussion to these relevant predictors. There is a main effect of vowel height, whereby low vowels have overall higher ratios than high vowels ($\beta = .55$, $p < .001$). There is no main effect of being stressed in the base. However, the interaction between Vowel Height and Stressed in Base indicates that being stressed in the base has an effect for mid vowels ($\beta = .69$, $p < .001$). A stressed base mid vowel is very different in a special suffix word (it is lower) and in a normal suffix word (it is higher), but an unstressed base mid vowel is approximately the same height in both word types. Low and

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	ESTIMATE	STD. ERROR	DF	T VALUE	PR (> |T|)	
(Intercept)	3.161	0.133	26.191	23.850	0.000	***
Vowel position from beginning 2	0.041	0.067	2398.415	0.617	0.537	
Vowel position from beginning 3	0.212	0.090	1284.281	2.368	0.018	*
Vowel position from beginning 4	0.053	0.139	745.796	0.384	0.701	
Stressed in base TRUE	0.061	0.134	881.201	0.454	0.650	
Vowel height low	0.554	0.108	36.367	5.127	0.000	***
Vowel height mid	0.028	0.123	18.666	0.225	0.824	
Log freq. base	0.097	0.041	23.851	2.378	0.026	*
Stressed in base TRUE:Vowel height low	–0.123	0.164	600.256	–0.753	0.452	
Stressed in base TRUE:Vowel height mid	0.689	0.187	779.435	3.685	0.000	***

Table 8 F1 difference model.

high vowels are approximately the same height in normal and special suffix words, regardless of base stress. Mid vowels show stress maintenance in special suffix words by maintaining vowel height, while high and low vowels do not.

The raw F1 models (F1 normalized by speaker) were built separately for each vowel. Recall that they include only the subset of vowels that are stressed in the base (/a, ɛ, i, ɔ, u/), thus excluding upper-mid vowels. These models confirm that lower-mid vowels stay lower-mid in special suffix words and raise in normal suffix words ($\beta = .38$, $p < .05$). There is no effect of suffix type for other vowels (/a/: $\beta = -.21$, $p = .07$; /i/: $\beta = .002$, $p = .98$; /u/: $\beta = .03$, $p = .80$). If there were to be another effect, we would expect it in /a/, which has been reported to raise slightly when unstressed (Barbosa & Albana 2004).

6 DISCUSSION

This study provides empirical evidence that words with special suffixes maintain stress on the same vowel that receives it in the independent base. Stressed base vowels show stress maintenance in special suffix words through duration and intensity, and mid vowels also show it through F1. Base stressed vowels are longer and slightly louder in special suffix words than in normal suffix words, and mid vowels maintain their height in special suffix words but reduce (by raising) in normal suffix words ([ʒeneˈɾɔza]; [ʒeneˌɾɔza-ˈmẽtʃi]: [ʒeneɾozi-ˈdadʒi]). Vowels that are not stressed in the independent base are approximately the same in special and normal suffix words: there is no stress to maintain. Although duration, intensity, and F1 show robust evidence of stress maintenance for mid vowels, this is not the case for low and high vowels. Base stressed low and high vowels are longer and louder in special suffix words than in normal suffix words, but these effects are small in magnitude and may be imperceptible. Regardless, duration and intensity systematically differentiate all vowels at the acoustic level.

The acoustic results point to clear stress maintenance for mid vowels, but not as obviously for low and high vowels. This distinction based on vowel height is expected for F1: mid vowels undergo the most reduction when unstressed. This reduction is large, and it is the only stressed-unstressed vowel quality alternation that speakers are explicitly aware of. However, the weaker effects for duration are surprising: duration could be used as a stronger correlate of stress maintenance for low and high vowels.

There are several possible interpretations for the finding that stress maintenance shows up robustly only for mid vowels, and much more weakly for low and high vowels: (a) special suffix words consist of a base that is prosodized as an independent phonological word to the exclusion of the suffix, but surface-level complications negate the acoustic correlates of stress maintenance; (b) there is no surface acoustic stress maintenance. Maintaining the phonological word analysis allows us to explain why base stressed vowels are longer and louder in special suffix words than in normal suffix words, and why mid vowels maintain their quality in special suffix words. This analysis is in line with previous work, and follows the assumption that lower-mid vowels are found in surface stressed positions (Câmara 1970b; Wetzels 1992; Vigário 2003; Toneli 2014; Guzzo 2018). While the effects for duration and intensity are small, they are acoustically present and may reflect a level of surface stress. Another possibility is that base stress is not maintained on the surface: some suffixes block neutralization, and the vowel was stressed at the point in the derivation when reduction applied. The lack of surface stress could explain the weaker effects of duration for low and high vowels. Unfortunately, it is not possible to distinguish these possibilities with acoustic data.

The results provide support for theories in which phonological and morphological processes interact. Apart from the proposed analysis—in which morphological structure determines cyclic spell-out—similar results can be achieved in rule-based accounts that allow cyclic application of phonological processes at each level of word formation (e.g. Lexical Phonology, Kiparsky 1982; Mohanan 1982). Constraint-based accounts could also achieve similar results. Stratal OT (Bermúdez-Otero 2018) uses the phonological cycle and stratification to apply phonological processes with constraints at different levels of word formation. Optimal Interleaving (Wolf 2008) uses constraints to control when affixes are introduced and when phonological processes occur. These types of analyses can obtain the correct results, but have nothing to say about why this particular set of suffixes in Brazilian Portuguese behaves as a group. While the phonological results are the same, there is no principled reason for the division between special and normal suffixes.

Analyses that divorce morphological structure from phonological structure are also possible. Special suffixes could be analyzed as simply subcategorizing for prosodic word bases (e.g. Bennett 2018). This analysis straightforwardly derives stress maintenance on the base, but lacks the explanatory power of a morphosyntactic argument in which the phonological facts can be related to shared morphological properties. This is particularly true for Brazilian Portuguese diminutives and superlatives, which share morphological properties relevant to determining spell-out domains. Even though *-mente* differs morphologically from diminutives and superlatives, they all share morphological characteristics that distinguish them as a set from normal suffixes. An analysis using output-output faithfulness is also possible: base stress maintenance is derived with constraints requiring similarity between the base and its derivative (Benua 1997). This approach treats affix groupings as arbitrary. Ferreira's (2005) account of Brazilian Portuguese diminutives uses this approach (see also Bachrach & Wager's 2007 critique), but does not take advantage of the fact that the special suffixes share morphosyntactic properties. Subcategorization and output-output faithfulness approaches relegates the co-occurrence of these morphological and phonological characteristics to chance.

Still other frameworks focus on psycholinguistic factors. In a morphological decomposibility approach, reduction (Hedia & Plag 2017) and stress maintenance on the base (Collie 2008) have been found to depend on relative frequencies of the base and derived word. The current study was not designed to investigate frequency effects, but this could provide an interesting area for future work. The boundary between special and normal suffixes in Brazilian Portuguese may be more gradient than current analyses allow for, and stress maintenance may be affected by psycholinguistic factors. If present, these effects would support theories that allow morphological information to be available late in the phonological/phonetic derivation.

The proposed analysis, which ties phonological similarities to morphological similarities, derives the phonological properties from deeper structural characteristics. Diminutives and superlatives, as modifiers, attach outside the functional head that categorizes the root, leading the base to be prosodized independently of the suffix. *-mente* forms a morphological compound composed of two roots. Each root is categorized separately, leading to separate spell-out and stress assignment. The results of the production study contribute to body of work providing acoustic evidence for underlying morphological structure.

7 CONCLUSION

This paper has explored the interaction between phonology and morphology in special and normal suffix words in Brazilian Portuguese. I analyze the special suffixes and normal suffixes as differing in morphological properties that are tied to their stress properties. Normal suffixes are categorizing heads that are spelled out with their bases, and undergo stress assignment and vowel reduction as a whole. Special suffixes attach above the first categorizing head, so that the base is spelled out and assigned stress independently of the suffix. This leads to stress maintenance on the base of words with special suffixes. I propose that diminutives and superlatives are modifiers, while *-mente* forms morphological and phonological compounds with the base. Phonologically, all special suffixes allow the base to be prosodized independently. This is mostly in line with previous work by Villalva (1994), Vigário (2003), Toneli (2014), and Guzzo (2018). Combining a DM analysis with a prosodic analysis provides reason for similar phonological structure. Both morphological and prosodic structure are necessary, the latter mediating between morphological structure and phonological processes. The grouping of suffixes into special vs. normal is not arbitrary: it is due to underlying morphological structure.

The production experiment provides acoustic evidence for stress maintenance on the base in special suffix words. The acoustic correlates are strongest for mid vowels, but also hold weakly for low and high vowels. Duration and intensity show evidence of stress maintenance for vowels of all qualities, but it is not clear if these results are real-world meaningful for low and high vowels since the differences are so small. For mid vowels, duration and F1 provide robust evidence of stress maintenance on the base. The production study supports previous theoretical work by finding a connection between morphological structure, prosodic structure, and the acoustic realization of stress. Finally, the results raise interesting questions about a potential gradient distinction between suffix classes, and possible frequency and psycholinguistic effects on stress maintenance in morphologically complex words.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Supplementary File 1.** Appendices. DOI: *https://doi.org/10.5334/gjgl.1045.s1*
- **Supplementary File 2.** Data file: Raw acoustic data for all speakers (in csv format). DOI: *https://doi.org/10.5334/gjgl.1045.s2*
- **Supplementary File 3.** Sound files and textgrids. Three speakers' audio is split in half for more manageable file sizes. DOI: *https://doi.org/10.5334/gjgl.1045.s3*

ABBREVIATIONS

AIC = Akaike Information Criterion, ADV = adverb, DM = Distributed Morphology DIM = diminutive, F = feminine, M = masculine, PL = plural, SG = singular, SUP = superlative

ETHICS AND CONSENT

This study was approved by the NYU IRB (IRB-FY2018-1442).

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COMPETING INTERESTS

The author has no competing interests to declare.

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