Journal of
Portuguese Linguistics

Becker, M., Nevins, A., Sandalo, F., & Rizzato, E. (2024). Prosodic generalizations in the Brazilian Portuguese diphthongal plural. *Journal of Portuguese Linguistics*, 4, pp. 1–31. DOI: https://doi.org/10.16995/jpl.9740

Open Library of Humanities

Prosodic generalizations in the Brazilian Portuguese diphthongal plural

Michael Becker, University of Massachusetts Amherst, US, michael@linguist.umass.edu
Andrew Nevins, Universidade Federal do Rio de Janeiro, BR; University College London, UK, a.nevins@ucl.ac.uk
Filomena Sandalo, Universidade Estadual de Campinas, BR, sandalo@iel.unicamp.br
Érick Rizzato, Universidade Estadual de Campinas, BR, erickrizzato@gmail.com

The diphthongal plural in Brazilian Portuguese is sensitive to three phonological factors: monosyllabicity, licensing of nasal diphthongs by stress, and vertical dispersion of oral diphthongs. We present an analysis that captures the gradient distribution of the Brazilian Portuguese plurals ending in diphthongs, both oral and nasal, using a probabilistic grammar based on the well-understood factors mentioned above. This grammar is trained on corpus data and is sensitive to prosodic generalizations; it correctly derives existing plurals while accurately generalizing beyond individual lexical items and predicting participants' choices in nonce word tasks. The results are incompatible with analyses that apply uniformly to all lexical items, as well as with those that simply memorize semipredictable plurals without incorporating phonologically-based generalizations.

1. Introduction[1]

One recurrent theme in the study of Brazilian Portuguese is the question of diphthongal plurals; these are the plurals of nouns and adjectives that end in the back glides: the oral [w] and its nasal counterpart [w̃]. The most frequent and productive pattern is the fronting of the glide to [j, j̃] before the plural [s], and if the preceding vowel is [ɐ̃], flopping the round feature of the glide onto the nucleus. Thus the word-final oral glide fronts in [ʒoɾˈnaw ~ ʒoɾˈnajs] 'newspaper(s)', while both fronting and flopping of the nasal glide are observed in [koɾaˈsɐ̃w̃ ~ koɾaˈsõj̃s] 'heart(s)'. A minority pattern of pluralization leaves the stem faithful (unchanged), with a simple suffixation of [s], as in [muˈzew ~ muˈzews] 'museum(s)', [ˈmɐ̃w̃ ~ ˈmɐ̃w̃s] 'hand(s)'. In addition to these two patterns, a smaller number of [ɐ̃w̃]-final nouns front the nasal glide without preserving the rounding, e.g., [ˈkɐ̃w̃ ~ ˈkɐ̃j̃s] 'dog(s)'.

Earlier research focused on deriving the plurals of individual lexical items, attributing the three synchronic plural patterns to three different etymological sources. Historically, the fronting of the back glides involved the deletion of intervocalic [l, n]. Thus, the plural [ʒoɾˈnajs] originated in a regular plural *[ʒoɾˈnales], with loss of the lateral in the plural first, and then in the singular many centuries later. Similarly, the plural [koɾaˈsõj̃s] originated in a regular plural [koɾaˈsones], with the consonantal [n] later disappearing from the paradigm, leading to nasal vocoids. The etymologically-oriented approach, which is present in modern linguistics since Mattoso Câmara (1953), is reviewed in Morales-Front & Holt (1997:397), who observe that "the principal difficulty in analyzing these cases is that in the plural they show one of three forms, which depend both historically and synchronically on the Latin etymological root. The need to posit input forms that are identical or similar to the Latin etyma has been established by Saciuk (1970), Brasington (1971), St. Clair (1971), Mira Mateus (1975) and Brakel (1979)". These views are broadly shared, including more recently in Huback (2007, 2010) and Pimenta (2019), a.o. The focus on exceptional items is found as early as D'Oliveyra (1536), who observed that plurals of final diphthongs are subject to "muitas eiçeições" nos "ditõgos" [many exceptions in the diphthongs].

We will refer to the works above as constituting the *lexicon-only* approach. Existing lexical items are derived from underlying representations that resemble their etymology. The works cited above provide no mechanism for capturing broader regularities in the grammar, and thus fail to make general predictions about novel forms – a shortcoming which applies independently of the degree of abstractness of the underlying representation of nasal diphthongs assumed in each.

[1] Thank you to Natasha Mourão for assistance in preparing the experimental stimuli. This project was supported by a FAPESP grant no. 2012/17869-7 Awarded to Filomena Sandalo. Thank you to Luiz Schwindt for his feedback.

This *lexicon-only* approach first came under criticism from Abaurre-Gnerre (1983), who observes that diphthongal plurals are semipredictable: [ɐ̃w̃]-final words most commonly pluralize to [õj̃s], but the change to [õj̃s] is blocked in monosyllables. Abaurre-Gnerre (p. 138) intuited that the differential treatment of monosyllables is systematic, and suggested the potential importance of a nonce word study. In this paper, we provide the nonce word study that Abaurre-Gnerre called for, we confirm the productivity of the monosyllabicity factor, and we further identify two other factors that partially predict the formation of plurals.

More recent research on the Brazilian Portuguese plural provided a quantitative perspective; rather than look at the derivation of each item, broader trends were identified. This includes corpus work on the distribution of the different plural forms, as well as nonce word tests ("wug-test", Berko, 1958; Menn & Ratner, 1999) to establish the productivity of the patterns (Becker et al., 2017, 2018; Schwindt et al., 2020, Schwindt 2021, Schwindt & Abaurre, 2022). All of these works identify the importance of monosyllabicity: the fronting of [w, w̃] to [j, j̃] is common in polysyllables, but rare in monosyllables. Stress matters as well: plurals with [ɐ̃j̃s] or [õj̃s] are blocked in unstressed syllables. Finally, these works identify the role of the laxness of the preceding vowel: the fronting of oral [w] to [j] is common after lax vowels, but less common after tense vowels. These three factors are observed in corpus studies, and as we will see below, apply productively to nonce words.

This literature also identified shortcomings of the lexicon-only, etymological view. Firstly, nouns do not always follow their etymology. For example, [deˈmɐ̃w̃] 'coat of paint' is derived historically from [ˈmɐ̃w̃ ~ ˈmɐ̃w̃s] 'hand(s), coat(s) of paint', and its normative plural is thus [deˈmɐ̃w̃s]. Yet the innovative or nonstandard plural [deˈmõj̃s] shows that polysyllables prefer the plural with [õj̃s], obeying the synchronic grammar and not the etymology (perhaps similar to the English past tense "grandstanded" being derived by regular rule, where the past tense of the sub-part "stand" isn't accessed). Moreover, glide fronting is found in loanwords that are more recent than the loss of intervocalic [l, n], and are thus "too late" for the etymological explanation to hold, e.g. [kokiˈtɛw ~ kokiˈtɛjs] 'cocktail(s)' (from English) and [giˈdɐ̃w̃ ~ giˈdõj̃s] 'handlebar' (from French). Another argument against strictly etymological approaches is based on alternations outside of the plural morphology. For example, the etymological [n] of [fejˈʒɐ̃w̃] 'bean' fails to surface before the suffix [adɐ] in [fejʒo-ˈadɐ] 'bean stew'. The etymological [n] of [liˈmɐ̃w̃] 'lime' surfaces before the same suffix in [limoˈn-adɐ] 'limeade', but not before the suffix [ejɾʊ] in [limo-ˈejɾʊ] 'lime-tree', providing clear counter-evidence for the idea of using the surface [n] in the derived form as evidence for an underlying /n/ in the base. In addition to the absence of etymological nasals, we observe the appearance of non-etymological nasals in recently created forms such as [suˈʃi ~ suʃin-aˈɾiɐ] 'sushi/sushi-house', or [tuˈpi ~ tupiˈn-ɔlogʊ] 'Tupinologist'. As we will show in the experimental study below, the extension of the three patterns of nasal diphthongal plurals to experimentally invented nonce words demonstrates that the patterns simply cannot be explained in terms of their etymological trajectory from Latin.

Returning to the plurals, **Table 1** offers a summary of the synchronic situation in Brazilian Portuguese, organized by the final segment of the stem. The regular plural consists of the addition of [-s] after vowels and [j, j̃], and the addition of [-is] after consonants. The plural is semipredictable for nouns and adjectives that end in a back glide [w, w̃]. As our focus on is these glide-final plurals, we gloss over some details with regular plurals, such as the lack of overt affix after [s]-final nouns with non-final stress, metaphony, and other processes; see Mattoso Câmara (1953), Abaurre-Gnerre (1983), Morales-Front & Holt (1997), Huback (2007), Gomes & Manoel (2010) for fuller descriptions and analyses.

		SG	PL	SG	PL	gloss
regular	a.	V	-s	soˈfa	soˈfa-s	'sofa'
		j		eˈɾɔj	eˈɾɔj-s	'hero'
		j̃		ˈifẽj̃	ˈifẽj̃-s	'hyphen'
	b.	ɾ	-is	ˈfloɾ	ˈfloɾ-is	'flower'
		s		naˈɾis	naˈɾiz-is	'nose'
semipredictable	c.	w	w-s	muˈzew	muˈzew-s	'museum'
	d.		j-s	aˈnɛw	aˈnɛj-s	'ring'
	e.	w̃	w̃-s	ˈsɔtɐ̃w̃	ˈsɔtɐ̃w̃-s	'attic'
	f.		ɐ̃j̃-s	ˈkɐ̃w̃	ˈkɐ̃j̃-s	'dog'
	g.		õj̃-s	boˈtɐ̃w̃	boˈtõj̃-s	'button'

Table 1: Overview of the Brazilian Portuguese plural by the final segment of the stem: regular generally (a-b), semipredictable when ending in a back glide (c-g).

We show in this paper that the fronting of [w, w̃] to [j, j̃] is preferred by default, but that this fronting alternation is blocked by three factors: the protection of monosyllables, the licensing of the nasal diphthongs [ɐ̃j̃, õj̃] by stress, and the preference for vertically dispersed oral diphthongs, preferring the lax [aj, ɛj, ɔj] over the tense [ej, oj].

The description in **Table 1** is based on the dialect(s) of São Paulo, and more generally, holds for any dialect that has fully merged final [l] with final [w] to create final diphthongs of the relevant type, as in most varieties of Brazilian Portuguese. The description and the proposed analysis in this paper are not fully applicable to dialects that maintain a final [l], as is common in European varieties, because in these dialects there is no oral [w ∼ j] alternation; only the nasal [w̃ ∼ j̃] alternation is observed. For these dialects, the reader is referred to Mateus & d'Andrade (2000), Freitas (2001), Vigário (2003), Collischonn & Quednau (2009), among others. The situation is more complicated in cases of dialect contact and/or change in progress, where speakers have access to both final [l] and final [w], as documented and analyzed in Collischonn & Quednau (2009), Schwindt (2021).

The evidence provided here reveals that lexical-only analyses do not generalize properly to nonce words, since they do not incorporate the prosodic and segmental trends that are learned from the lexicon and used in the formation of novel words. Lexicon-only analyses that use a completely regular grammar neatly separate the grammar from the lexicon (rules vs words), encoding the patterning of individual items solely in the lexicon. In a lexical-only analysis, the distribution of plural types is "arbitrary" (Huback 2007), leaving no account for the observed productive trends in the distribution of pluralization patterns.

We start below with a description of the phonological trends in the extant lexicon, based on our own studies and previous work in §2. The proposed analysis models the lexical data for both oral and nasal diphthongal plurals with a probabilistic grammar in §3. The predictions of this grammar as extended to nonce words are provided in §4. We present an overall set of conclusions in §5.

2. Predictors of diphthongal plurals in the lexicon

Portuguese nouns that end in a back glide are pluralized in one of three ways, as seen in **Table 1c-g**. First, the simple addition of [s], as in [muˈzew ∼ muˈzews] 'museum(s)', [ˈsɔtɐ̃w̃ ∼ ˈsɔtɐ̃w̃s] 'attic(s)', leaving the stem intact, i.e., a faithful diphthongal plural. Or, the glide becomes front and unrounded, as in [aˈnɛw ∼ aˈnɛjs] 'ring(s)', [ˈkɐ̃w̃ ∼ ˈkɐ̃j̃s] 'dog(s)'. Finally, for nasal diphthongs, but not oral ones, and only when the vowel preceding the glide is [ɐ̃], a third option appears: flopping the roundness of the glide onto the preceding vowel, as in [boˈtɐ̃w̃ ∼ boˈtõj̃s] 'button(s)'. No vowel other than [ɐ̃] alternates this way, and thus for nasal diphthongs such as [ɐ̃w̃], there are three potential plural outputs.

To study the diphthongal plurals with the nasal glide [w̃], we employed the Tang corpus (Tang et al., 2013[2]), which is based on a total of 51 million tokens taken from film subtitles. All the items spelled with final ⟨ãos⟩, ⟨ães⟩, or ⟨ões⟩ were extracted. The items were then paired with their ⟨ão⟩-final singular; items with no such singular, e.g., ⟨mãe⟩ 'mother', were discarded. This method provided a total of 1295 plurals, of which 8 were monosyllabic, 5 trochaic (= polysyllabic with penultimate stress) and 1282 iambic (= polysyllabic with final stress).

[2] https://www.kevintang.org/Tools.html.

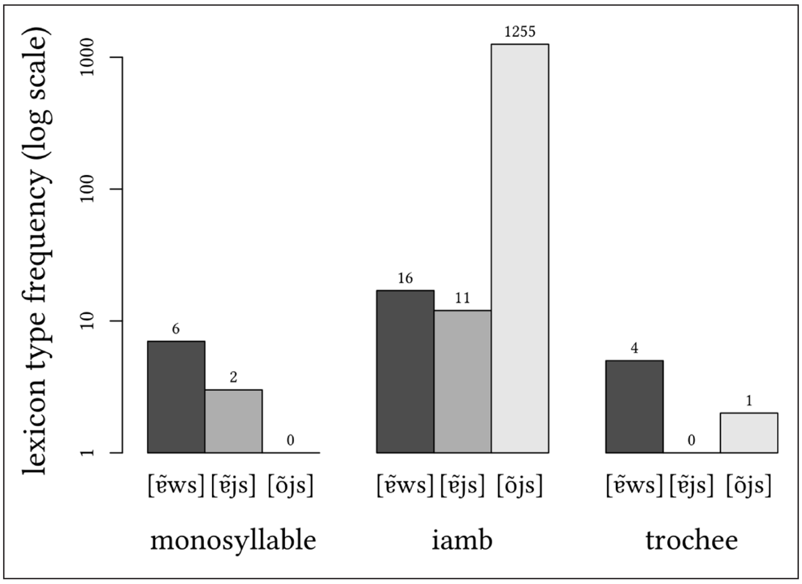

Figure 1: The distribution of plurals in the Tang corpus (Tang et al., 2013). The preferred plural is [õj̃s] for iambs and [ɐ̃w̃s] otherwise.

The results, presented in **Figure 1**, shows that [õj̃s] plurals are the most common overall at 97%, and that they are almost entirely limited to iambs. For monosyllables and trochees, [ɐ̃w̃s] is the preferred surface form, and secondarily, [ɐ̃j̃s] is more common in monosyllables than in trochees. **Figure 1** uses type frequencies; using token frequencies paints a very similar picture. These results largely replicate and confirm those in the corpus studies from Huback (2011) and from Schwindt et al. (2020), who use larger corpora with similar methodologies. In Schwindt et al. (2020), the plurals of monosyllables are roughly 80% [ɐ̃w̃s] and 20% [ɐ̃j̃s], while trochees are 90% [ɐ̃w̃s].

For the oral glide [w], we rely on the corpus statistics reported in Becker et al. (2017). They show that the backness alternation, as in [aˈnɛw ∼ aˈnɛjs] is the most common (see **Table 1d**). The backness alternation is dispreferred in monosyllables (29% in monosyllables vs. 88% in polysyllables) and following tense vowels (69% following a tense vowel vs. 89% following a lax vowel). The type frequencies for the nasal and oral glides are provided in Appendix A.

Comparing the nasal and oral back glides, two points of similarity emerge: the backness alternation is preferred/most common in both, and the alternation is dispreferred in monosyllables in both. The nasal and oral alternation differ in their sensitivity to the resulting diphthongs: the nasal diphthongs are sensitive to stress (only [ɐ̃w̃] is allowed to be stressless — in general, nasal vowels and diphthongs are more restricted in their distribution in Brazilian Portuguese), while the oral diphthongs are sensitive to vertical dispersion (tense vowel + glide diphthongs are dispreferred relative to lax vowel + glide diphthongs). Nasal vowels in Brazilian Portuguese do not contrast in laxness, and therefore by definition are not sensitive to the laxness-based restrictions on oral vowels.

3. Representing lexical trends in the grammar

This section presents a probabilistic grammar that is trained on the distribution of plurals in the lexicon, and predicts a pattern of productivity in novel words. The grammar uses lexically-specific constraints to correctly derive the plurals of existing lexical items. The grammar is implemented using the constraint-based MaxEnt framework (Maximum Entropy, also known as a multinomial regression, Goldwater & Johnson, 2003; Smolensky & Legendre, 2006), which is a probabilistic version of Optimality Theory (Prince & Smolensky, 1993/2004). The tableaux for the analysis are provided in Appendix A.

First, we show how to derive the default alternations of backness and rounding in §3.1, and then explain how the analysis distinguishes existing words from novel words in §3.2. The default backness/rounding alternations are blocked by three phonological factors: protection of initial syllables (§3.3), a requirement that [ɐ̃j̃] and [õj̃] be stressed (§3.4), and the preference for oral diphthongs that start with a lax vowel (§3.5). We summarize the analysis in §3.6.

3.1 Backness alternation and flopping by default

We start with the most frequent nasal pattern, the [ɐ̃w̃ ~ õj̃s] alternation, which is also the most preferred in nonce words (see §4 below). In a constraint-based grammar, two main questions must be answered: what makes [õj̃s] preferred over [ɐ̃j̃s], and what makes [õj̃s] preferred over [ɐ̃w̃s]?

Adopting the proposal in Schwindt & Wetzels (2016), the [round] feature of the singular [w̃] can receive one of two treatments: it can be deleted, resulting in plural [ɐ̃j̃s], or it can be retained and flopped leftward from the coda to the nucleus in [õj̃s]. The proposed mappings are summarized in **Figure 2**, where dotted lines show deletion or fusion, and a solid arrow shows the flopping of the [round] feature from the [w̃] leftward. The plural suffix has an allomorph /-is/, found after all consonants (including glides), but the analysis can also work with the underlying representation /-s/; see discussion below. Only [ɐ̃w̃s] plurals involve deletion, in this case the deletion of the suffix vowel, and thus only these violate MAX-V. Candidates that involve deleting anything from the root can be blocked by MAXROOT. The [ɐ̃j̃s] and [õj̃s] plurals are both derived via fusion of the stem [w̃] with the suffix [i], violating UNIFORMITY (McCarthy & Prince, 1995) which penalizes the fusion of two segments into one, but we omit this constraint from consideration because it does not distinguish [ɐ̃j̃s] from [õj̃s]. In [ɐ̃j̃s] plurals, the stem [w̃] loses its rounding, which violates MAX(round). In [õj̃s] plurals, the round feature does not delete, but rather flops over to the preceding vowel, violating *FLOP(round), which belongs to the

*Flop family of faithfulness constraints (McCarthy 2003). The three patterns are thus derived by referring to three different faithfulness violations.

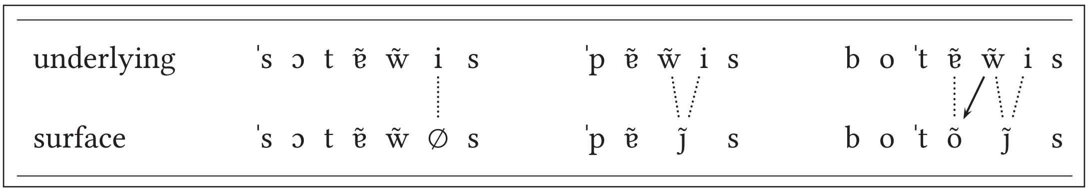

Figure 2: Proposed correspondence relations in [ẽw̃s], [ẽj̃s], and [õj̃s] plurals.

The analysis can match the high frequency of [õj̃s] in the lexicon by making the weight of *Flop(round) substantially smaller than the weight of Max(round), as seen in **Table 2**, which shows the derivation of a plural for the nonce word [taˈgẽw̃]. The predicted acceptability is 98% for [õj̃s] and 2% for [ẽj̃s]. Candidates that have no deletion, e.g., [taˈgẽw̃is] or [taˈgẽw̃j̃s], violate undominated markedness constraints against onset [w̃] or triphthongs and will not be included. We also omit many other logically possible candidates, e.g., ones with fortition of the glide to a less marked onset, blocked by faithfulness.

In MaxEnt, constraints are weighted, and each violation is multiplied by the weight of the constraint that assigns it. Summing the weighted violations of each candidate gives its harmony ($\mathcal{H}$). For example, in **Table 2**, the first candidate has a violation of Max-V, which is multiplied by 5.9, for a harmony of −5.9; violations are always negative. To convert harmonies into probabilities, each harmony is exponentiated, and the result is divided by the sum of the exponentiated harmonies in the tableau.

The weights in **Table 2** were computed using the software provided in Hayes & Wilson (2008). The program is given the lexical statistics from §2, and it uses them to calculate constraint weights that match the lexicon as closely as possible.

/taˈgẽw̃ + is/	**Max-V** $w = 5.9$	**Max (round)** $w = 3.9$	***Flop (round)** $w = 0$	$\mathcal{H}$	p
a. taˈgẽw̃s	−1			−5.9	≈0
b. taˈgẽj̃s		−1		−3.9	.02
c. ☞ taˈgõj̃s			−1	0	.98

Table 2: For nasal iambic stems, [õj̃s] plurals are predicted at 98%, shown with the nonce word [taˈgẽw̃].

To assign the highest probability to [õj̃s], the analysis must also penalize [ɐ̃w̃s], and therefore [ɐ̃w̃s] must violate some constraint more severely than [õj̃s]. As mentioned above, we propose that the plural suffix has an allomorph /-is/, and [ɐ̃w̃s] plurals delete the suffix vowel, violating MAX-V. If, however, one assumes that the plural suffix is underlyingly /-s/, the plural [taˈgɐ̃w̃s] is completely faithful to /taˈgɐ̃w̃ + s/. If [ɐ̃w̃s] plurals are faithful, the only thing that can penalize them is markedness. One might propose a markedness constraint that targets the juncture between the back glide and the following [s], perhaps tying them to the tendency for an excrescent [j] before a tautomorphemic final [s], as discussed in Nevins (2015). The application of this proposal hits a snag in the São Paulo dialect(s) that we study here, since most speakers do not have an excrescent [j] in the plurals of vowel-final words, e.g. [soˈfa-s] 'sofas', *[soˈfaj-s] (**Table 1a**).

Given the difficulty of the markedness based approach, we maintain the position that [ɐ̃w̃s] is in fact unfaithful. In this we follow Becker et al. (2018), who proposed that the plural suffix has two allomorphs: /-s/ selected for vowel-final stems and /-is/ selected for consonant-final stems. Final glides, like all consonants, select the allomorph /-is/, and the suffixal vowel deletes in [ɐ̃w̃s] plurals, violating MAX-V, as seen in **Table 2**. The selection of /-is/ for consonant-final stems is transparent for stems that end in [ɾ, s] (**Table 1b**), and opaque for stems that end in a glide. With the front glides, the junctures *[ji] and *[j̃i] are regularly simplified to [j] and [j̃], e.g., /eˈɾɔj + is/→ [eˈɾɔjs] 'hero(s)' (**Table 1a**; also see Kawasaki 1982). With the back glides, the ill-formed junctures [wi] and [w̃i] are repaired either via deletion of the suffixal [i], allowing the stem to surface faithfully, or via fusion of the glide with the following vowel, resulting in a front glide [j] or [j̃] (**Table 2**).

The analysis of oral [w] is exactly parallel, except that flopping the [round] feature onto an oral vowel is blocked, as seen in **Table 3** with the derivation of the nonce /pɾiˈzɛw/. The violations and harmonies ($\mathcal{H}$) in **Table 3** are otherwise identical to those in **Table 2**. The absence of competition from the flopped candidate allows most of the probability to be assigned to the candidate that deletes rounding, in this case predicting an acceptability of 88% for the backness alternation.

/pɾiˈzɛw + is/		MAX-V $w = 5.9$	MAX (round) $w = 3.9$	*FLOP (round) $w = 0$	$\mathcal{H}$	p
a.	pɾiˈzɛws	−1			−5.9	.12
b. ☞	pɾiˈzɛjs		−1		−3.9	.88

Table 3: For oral iambic stems, [js] plurals are predicted, shown with the nonce word [pɾiˈzɛw].

The flopping of rounding onto a vowel is only possible with [ɐ̃] and no other vowel. There is a wide range of analyses that can prevent the flopping of rounding onto other vowels, and the details are not crucial to the current discussion. Any mechanism that blocks, e.g., *[pɾiˈzɛw ∼ pɾiˈzɔjs] would work. Generally speaking, Brazilian Portuguese is rich in height and laxness alternations, but very limited in backness and rounding alternations, suggesting a central role for IDENT(back) in the language.

To summarize, the default/most frequent plural patterns are [ɐ̃w̃ ∼ õj̃s] and [w ∼ j]; we derive both from the interaction of three faithfulness constraints. For the oral [w], MAX-V penalizes the deletion of the underlying /i/ from the plural suffix, while MAX(round) penalizes the deletion of rounding from the stem. The heavier weight of MAX-V predicts an acceptability of 88% for the [w ∼ j] alternation in the default case (=polysyllabic stem with a final lax vowel). For the nasal [w̃], the same constraints and the same weights, with the addition of a candidate that flops rounding leftward, predicts an acceptability of 98% for the [ɐ̃w̃ ∼ õj̃s] alternation in the default case (=polysyllabic stem with final stress). *FLOP(round) has a weight of zero, and therefore the penalty it assigns to [õj̃s] plurals has no effect.

3.2 Deriving existing lexical items

In addition to predicting the acceptability of novel plural forms, the grammar should also be tasked with deriving the plurals of existing lexical items. For example, the noun [sidaˈdɐ̃w̃] ‘citizen’ is observed in the corpus we examined only with the plural [sidaˈdɐ̃w̃s], and not [sidaˈdõj̃s] as expected for a polysyllable – although the form [sidaˈdõj̃s] is indeed found in other corpora (Huback, 2010). What prevents the grammar from generating [sidaˈdõj̃s] as the plural?

One possibility is to use the USELISTED framework (Zuraw, 2000). In this theory, the speaker memorizes the derived forms they encounter, e.g., [sidaˈdɐ̃w̃s], and these memorized forms are also used to train a productive grammar. The constraint USELISTED penalizes productively formed plurals, ensuring that memorized plurals are used when they are known to the speaker. Further, USELISTED penalizes frequent forms more than rare forms, ensuring that frequently used words are produced correctly more often, as documented by Huback (2010).

Moore-Cantwell (2017), Moore-Cantwell & Pater (2016) propose a more nuanced framework in which lexical items are associated with lexically-specific constraint weights. The general grammar and the lexically-specific weights are both learned simultaneously from the environment (a corpus). Lexically specific weights are under pressure to minimize, moving the maximal amount of explanatory power to the regular grammar, leaving lexically specific constraints with the minimal weight that is needed to resist the regular grammar. For [õj̃s] plurals such as [boˈtɐ̃w̃ ∼ boˈtõj̃s] ‘buttons’, the regular grammar already assigns 98% of the probability to the correct [boˈtõj̃s]; the lexically specific constraints have the modest task of bringing this probability up closer to 100% (but not exactly 100%; MaxEnt grammars can get arbitrary close but not reach

100%). This is shown in **Table 4**, where the three general faithfulness constraints seen in §3.1 above are augmented with three lexically specific versions of them: MAX-V-botẽw̃, MAX(round)-botẽw̃, and *FLOP(round)-botẽw̃. The first two penalize the unattested forms *[boˈtẽw̃s] and *[boˈtẽȷ̃s]; the third one is assigned a weight of zero, since [boˈtõȷ̃s] should not be penalized. The weights of the lexically-specific constraints were calculated with the same software as above, providing the attested plural [boˈtõȷ̃s] at 100%. We omitted the zero-weighted *FLOP(round)-botẽw̃ from **Table 4**, but it was included in the analysis.

/boˈtẽw̃ + is/	**MAX-V** w **= 5.9**	**MAX (round)** w **= 3.9**	***FLOP (round)** w **= 0**	**MAX-V** *botɒ̃w̃* w **= 3.7**	**MAX(r)** *botɒ̃w̃* w **= 5.2**	$\mathcal{H}$	p
a. boˈtẽw̃s	−1			−1		−9.6	≈0
b. boˈtẽȷ̃s		−1			−1	−9.1	≈0
c. ☞ boˈtõȷ̃s			−1			0	≈1

Table 4: For the item [boˈtẽw̃], lightly-weighted lexically-specific clones of MAX-V and MAX(round) ensure that the attested [boˈtõȷ̃s] is optimal.

Polysyllables with a plural in [ẽw̃s] or [ẽȷ̃s], such as [sidaˈdẽw̃ ~ sidaˈdẽw̃s] 'citizen(s)', diverge more strongly from the regular grammar, which hardly assigns any probability at all to the attested plural. The lexically-specific constraints must counter the grammar with larger weights, as seen in **Table 5**. Here, the two lexically-specific constraints MAX(round)-sidadẽw̃ and *FLOP(round)-sidadẽw̃ have weights that are at least twice as large as those in **Table 4**. Depending on one's theory of learning, larger weights may take longer to acquire, and/or may require more exposure (greater token frequency). It is thus predicted that plurals such as [sidaˈdẽw̃s] would require more time and/or more exposure to learn correctly.

/sidaˈdẽw̃ + is/	**MAX-V** w **= 5.9**	**MAX (round)** w **= 3.9**	***FLOP (round)** w **= 0**	**MAX(r)** *sidadɒ̃w̃* w **= 10.4**	***FLOP(r)** *sidadɒ̃w̃̃* w **= 14.1**	$\mathcal{H}$	p
a. ☞ sidaˈdẽw̃s	−1					−5.9	≈1
b. sidaˈdẽȷ̃s		−1		−1		−14.3	≈0
c. sidaˈdõȷ̃s			−1		−1	−14.1	≈0

Table 5: For the item [sidaˈdẽw̃], lexically-specific clones of MAX(round) and *FLOP(round) ensure that the attested [sidaˈdẽw̃s] is optimal.

Huback (2011) studied the effect of token frequency in the diphthongal plurals, and found that frequent items are produced with their normative plural more reliably than low frequency items. For example, comparing two words whose plural is normatively [ẽw̃s], Huback observes that medium frequency [kɾisˈtẽw̃] 'Christian' is produced with its normative plural more reliably than low frequency [vuwˈkẽw̃] 'vulcano'. Such effects can be incorporated into a future version of the model we use here, for example by reducing the plasticity of lexically specific constraints.

Finally, we show in **Table 6** the treatment of an item that has multiple plurals, such as [gwaɾʤiˈẽw̃ ~ gwaɾʤiˈẽj̃s, gwaɾʤiˈõj̃s] 'guardian(s)', where the learning software was provided with two plurals that are equally frequent. The given distribution was learned by adjusting the weights of the lexically-specific constraints appropriately; the learner is equipped to learn any combination of plurals for a given lexical item, while at the same time learning a general grammar that applies productively to novel items. The observed distribution that the learner encounters in its environment is learned and encoded in the grammar with only one mechanism: adjusting constraint weights. The underlying representation for any given lexical item remains unchanged.

/gwarʤiˈẽw̃ + is/	**MAX-V** w **= 5.9**	**MAX (round)** w **= 3.9**	***FLOP (round)** w **= 0**	**MAX-V** *gwarʤiõw̃* w **= 6.3**	***FLOP(r)** *gwarʤiõw̃* w **= 3.9**	$\mathcal{H}$	p
a. gwarʤiˈẽw̃s	−1			−1		−12.2	≈0
b. ☞ gwarʤiˈdẽj̃s		−1				−3.9	≈.5
c. ☞ gwarʤiˈõj̃s			−1		−1	−3.9	≈.5

Table 6: For the variable item [gwaɾʤiˈẽw̃], lexically-specific clones of MAX-V and *FLOP(round) generate variability between [gwaɾʤiˈẽj̃s] and [gwaɾʤiˈõj̃s].

Items with multiple plurals pose an insurmountable problem for lexical-only analyses, since a word like [gwaɾʤiˈẽw̃] would require two separate underlying representations, without any mechanism that can represent native speaker knowledge of their statistical distribution or deployment choice in real-time.

An intermediate approach to learning alternations is offered in Pater et al. (2012), where surface forms are used to construct "UR constraints"; for example, the paradigms such as [boˈtẽw̃ ~ boˈtõj̃s] would generate two underlying representations for the stem, /boˈtẽw̃/ and /boˈtõj̃/, with the first underlying representation selected in the singular and the second underlying representation selected in the plural. This approach is similar to the lexically-specific constraints we propose here, and crucially, it does not attempt to create abstract underlying representations that reproduce the etymology.

The analysis we provide here builds on the insights in Abaurre-Gnerre (1983), who proposes that the regular grammar produces [õj̃s] plurals, while [ɐ̃w̃s] and [ɐ̃j̃s] plurals are derived via lexical marking (diacritics); in her analysis, the two plurals of [gwarʤiˈɐ̃w̃] are derived via optionality of the lexical marking. Missing from Abaurre-Gnerre (1983), however, is a mechanism for the prosodic factors that guide pluralization. In the next section, we show how our analysis encodes prosodic generalizations in terms of competition between faithfulness constraints, formalized with a learning mechanism that captures the statistical trends that these constraints are able to capture.

3.3 Protection of monosyllables

In [ɐ̃w̃]-final monosyllables, stem changes such as deletion or flopping of the [round] feature occur in the more prominent initial syllable of the word, where they violate initial syllable faithfulness (Barnes, 2006; Becker, 2009, Becker et al., 2011, 2017; Beckman, 1997, 1998; Casali, 1998; Jesney, 2011; Steriade, 1994; Trubetzkoy, 1939). Here we follow Becker et al. (2018), who attribute the special patterning of monosyllables in Portuguese to the crosslinguistic protection of initial syllables more generally (Becker et al., 2012). Thus, in the nonce plural mapping /ˈfɐ̃w̃ + is/ → [ˈfɐ̃j̃s], as in **Table 7b**, the deletion of [round] violates both general MAX(round) and the specific MAX(round)-σ1, since the nasal glide [j̃] surfaces in the initial syllable. In the MaxEnt grammar, a violation of the general MAX(round) incurs a penalty of 3.9, and a violation of the specific MAX(round)-σ1 incurs an additional penalty of 2.7. Similarly, the mapping /ˈfɐ̃w̃ + is/ → [ˈfõj̃s], as in **Table 7c**, incurs violations of the general *FLOP(round) and the specific *FLOP(round)-σ1. Monosyllabic [ɐ̃w̃s] plurals, exactly like polysyllabic [ɐ̃w̃s] plurals, violate MAX-V. The suffixal vowel is equally absent from these plurals, and thus never violates any positional versions of MAX-V. With these constraints and weights, the grammar's prediction for a monosyllable is an acceptability of 67% for the [ɐ̃w̃s] plural and 33% for the [ɐ̃j̃s] plural.

/ˈfɐ̃w̃ + is/		MAX-V $w = 5.9$	MAX (round) $w = 3.9$	MAX-σ1 (round) $w = 2.7$	*FLOP (round) $w = 0$	*FLOP- σ1 (round) $w = 15.6$	$\mathcal{H}$	p
a. ☞	ˈfɐ̃w̃s	−1					−5.9	.67
b.	ˈfɐ̃j̃s		−1	−1			−6.6	.33
c.	ˈfõj̃s				−1	−1	−15.6	≈0

Table 7: For monosyllabic nasal stems, such as the nonce word [ˈfɐ̃w̃], [ɐ̃w̃s] plurals are predicted

Turning to monosyllables with a lax oral vowel [a, ɛ, ɔ] in their nucleus, these parallel the nasal monosyllables, just like polysyllables with a lax vowel parallel the nasal polysyllables. As seen in **Table 8**, no constraints distinguish nasal [ˈfẽw̃s], [ˈfẽȷ̃s] from oral [ˈbrɔws], [ˈbrɔjs], and therefore the grammar predicts the same rate of backness alternations in both cases. In the corpora we use here, the backness alternation has a type frequency of 41% in monosyllables with a lax vowel, compared to a type frequency of 25% in monosyllables with [ẽw̃]; our analysis averages these two together and predicts a backness alternation rate of 33% in both cases. Here, the analysis does not perfectly match the corpus type frequencies, because there is no constraint that distinguishes oral and nasal glides. We show in §4.5 that the predictions of the model are strongly correlated with speakers' behavior.

/ˈbrɔw + is/		MAX-V $w = 5.9$	MAX (round) $w = 3.9$	MAX-σ1 (round) $w = 2.7$	*FLOP (round) $w = 0$	*FLOP-σ1 (round) $w = 15.6$	$\mathcal{H}$	p
a. ☞	ˈbrɔws	−1					−5.9	.67
b.	ˈbrɔjs		−1	−1			−6.6	.33

Table 8: For monosyllabic oral stems, such as the nonce word [ˈbrɔw], [ws] plurals are predicted.

The effect of monosyllabicity is documented in Huback (2010, 2011), who suggests that monosyllables are controlled by a local "schema" (Bybee & Slobin, 1982), and that they "represent a separate class in the mental lexicon". In our analysis, monosyllables are not separate, but alternations in monosyllables are penalized by initial syllable faithfulness. The difference between the two proposals is that putting monosyllables in a separate class allows monosyllables to be derived differently, e.g., they may undergo a change that polysyllables are immune from. Initial syllable faithfulness makes a stronger prediction: monosyllables can only be protected from change, and cannot undergo a change that polysyllables are immune from. An additional advantage of initial syllable faithfulness constraints is that they apply to both nasal and oral diphthongs, protecting both types of monosyllables with the same mechanism.

3.4 Licensing of nasal diphthongs

In nouns with non-final stress that end in [ẽw̃], the plural most commonly maintains the diphthong faithfully. This result follows straightforwardly from the language-wide distribution of nasal diphthongs, most of which are strictly required to be in the stressed syllable. In **Table 9**, the candidates with unstressed [ẽȷ̃s] and [õȷ̃s] are penalized by License-ẽȷ̃/ˈσ and License-õȷ̃/ˈσ, which assign violation marks to these diphthongs in unstressed syllables. The plural [ɐ̃w̃s] is selected not because it is faithful, but because it is the least marked in this context.

These licensing constraints, which are employed in **Table 9**, reflect more general trends in the language, and form part of a larger family of Positional Licensing constraints that crosslinguistically allow more segmental contrasts in stressed syllables than in corresponding unstressed ones. In word-final unstressed position, only two nasal diphthongs are allowed: [ɐ̃w̃] and [ẽj̃]; the only exception is the nasal diphthong in the one word [ˈbẽj̃sõj̃s] 'blessings'. While [ɐ̃w̃] has a high type frequency both in stressed and unstressed syllables, most other nasal diphthongs of the language have low type frequencies, and are almost completely limited to stressed syllables. The diphthong [ɐ̃j̃] appears in a handful of roots, e.g., [ˈmɐ̃j̃] 'mother', [ˈkɐ̃j̃bɾɐ] 'cramp', and their derivatives, and in plurals of [ɐ̃w̃]-final words, always in a stressed syllable. As for [õj̃], it appears in the single item [ˈpõj̃] 'put.3sg' and its derivatives, and in the plurals of [ɐ̃w̃]-final words, again limited to the stressed syllable, with the exception of the plural [ˈbẽj̃sõj̃s] 'blessings'.

The derivation of unstressed [ɐ̃w̃] is shown in **Table 9**, where the [ɐ̃j̃s] and [õj̃s] plurals are penalized by the markedness constraints that require nasal diphthongs to be licensed by stress. In this grammar, the word [ˈbẽj̃sõj̃s], which is the only word in the language with an unstressed [õj̃], causes the weight of Lic-õj̃/ˈσ to be lower than the weight of Lic-ɐ̃j̃/ˈσ. Not all speakers have this unusual word; for speaker who do not, the two markedness constraints will have similar weights, ruling out unstressed [õj̃] and unstressed [ɐ̃j̃] equally.

/ˈsɔtɐ̃w̃ + is/	Max-V $w = 5.9$	Max (round) $w = 3.9$	*Flop (round) $w = 0$	Lic-ɐ̃j̃/ˈσ $w = 11.7$	Lic-õj̃/ˈσ $w = 7.3$	$\mathcal{H}$	p
a. ☞ ˈsɔtɐ̃w̃s	−1					−5.9	.80
b. ˈsɔtɐ̃j̃s		−1		−1		−15.6	≈0
c. ˈsɔtõj̃s			−1		−1	–7.3	.20

Table 9: For trochaic stems, [ɐ̃w̃ s] plurals are predicted.

While [ɐ̃w̃] and [ẽj̃] are the only nasal diphthongs allowed in word-final unstressed position, even these two are optionally reduced and oralized to [ʊ, ɪ] respectively (Bopp da Silva, 2005; Medeiros et al., 2021; Schwindt & Bopp da Silva, 2009). For example, [ˈɔɾfɐ̃w̃] 'orphan' may be reduced to [ˈɔɾfʊ̃, ˈɔɾfʊ]. We thus see that nasal diphthongs in Brazilian Portuguese strongly require stress, and even the more broadly distributed [ɐ̃w̃] and [ẽj̃] are eliminated from final unstressed syllables in some cases.

To summarize the analysis so far, nasal diphthongs appear in three environments: stressed non-initial syllable (the default), stressed initial syllable (protected by positional faithfulness), and unstressed syllable (restricted by markedness).

3.5 Vertical dispersion in oral diphthongs

Turning back to the oral [w], the [w ~ j] alternation is most acceptable at 88% (see **Table 3** above) in polysyllables that have a lax vowel [a, ɛ, ɔ] in their final syllables, but the acceptability of the alternation is lowered to 76% when the preceding vowel is one of the tense oral vowels [e, i, o, u], as seen in **Table 10** below. Following Becker et al. (2017, 2018), we assume that the alternation is disfavored after a tense vowel due to the illformedness of the morphologically derived diphthongs [ej, oj] (while underived /ej, oj/ are acceptable). The tense vowel offers poor vertical distinction from the glide [j] compared to the more acceptable difference in height between a lax vowel and a glide in [aj, ɛj, ɔj].

Table 10 shows the derivation of a nonce word such as [ˈfiosew] with a tense oral vowel before a final [w]. The constraint *SHALLOWDIPHTHONG reduces the probability of the [w ~ j] alternation after a tense vowel in all contexts, regardless of stress or monosyllabicity. Formally, *SHALLOWDIPHTHONG is a markedness constraint that assigns one violation each to [ej], [oj], and [uj] but not to [ɛj], [ɔj] or [aj]; compare to the similar constraint *HEARCLEAR (Minkova & Stockwell, 2003). The analysis predicts an acceptability of 76% for the [w ~ j] alternation in a polysyllable regardless of stress; the prediction for a stressed syllable in, e.g., [muˈzew] 'museum' would be identical. In monosyllables, *SHALLOWDIPHTHONG works in tandem with MAX(round)-σ1 to reduce the acceptability of the [w ~ j] alternation from 33% (see **Table 8**) to 17%.

/ˈfiosew + is/		**MAX-V** $w = 5.9$	**MAX (round)** $w = 3.9$	***FLOP (round)** $w = 0$	***SHALLOW DIPHTHONG** $w = .8$	$\mathcal{H}$	p
a.	ˈfiosews	−1				−5.9	.24
b. ☞	ˈfiosejs		−1		−1	−4.7	.76

Table 10: A constraint against morphologically derived shallow diphthongs reduces the predicted acceptability of the [w ~ j] alternation for the nonce word [ˈfiosew].

The markedness of the shallow diphthongs [ej, oj] relative to the better dispersed [aj, ɛj, ɔj] finds support from work on the typological distribution of diphthongs by Kubozono (2001), who observes that diphthongs with greater height dispersion are more common in the world's languages, with [aj] being the most common. For further exploration of diphthong dispersion in Brazilian Portuguese, see Nevins (2012), and more recently, Eberle (2022).

The sensitivity of the [w ~ j] alternation to the laxness of the preceding vowel is also seen in innovative or nonstandard plurals, which are only observed following a lax vowel, e.g., with [a] in [deˈɡɾaw ~ deˈɡɾajs] 'step(s)' alongside the standard plural [deˈɡɾaws], and with [ɛ] in [tɾoˈfɛw ~ tɾoˈfɛjs] 'trophy(s)' alongside the standard plural [tɾoˈfɛws]. There are no parallel examples of innovative plurals following a tense vowel.

3.6 Summary of the analysis

We presented a probabilistic grammar that partially matches the frequencies of plurals in the lexicon using a set of phonological constraints. By default, nouns that end in a back glide [w, w̃] undergo a backness alternation to the corresponding front glide [j, j̃] due to fusion with the vowel [i] of the plural suffix. The rounding of the stem glide flops leftward if the preceding nucleus is [ɐ̃], and the rounding is deleted otherwise. The acceptability of this default alternation is reduced by three phonological factors: the protection of monosyllables by initial syllable faithfulness, the licensing of the nasal diphthongs [ɐ̃j̃, õj̃] by stress, and a dispreference for the poorly dispersed diphthongs [ej, oj]. The tableaux that were used to train this grammar are provided in Appendix A. In addition to the general constraints in these tableaux, which apply productively to any word, existing or novel, we also used lexically-specific constraints to correctly derive established plurals of existing lexical items.

The analysis matches lexical statistics based on grammatical principles, unlike general-purpose statistical models that are not similarly constrained. For example, the backness alternation is predicted to be equally acceptable in monosyllables with [ɐ̃] and monosyllables with a lax nucleus [a, ɛ, ɔ], despite the frequency differences in the corpora, since both kinds of plurals are derived using the same set of constraints. Similarly, the alternation is predicted to have the same acceptability in polysyllables that have a tense nucleus in their final syllable regardless of stress. The proposed analysis is built on general grammatical principles that are well-founded typologically and have broad application in Brazilian Portuguese and beyond.

4. Productive application to nonce nouns

To test how speakers of Brazilian Portuguese apply their plural morphology productively in [w̃]-final nouns, and to measure the effect of monosyllabicity and stress on the choice of the plural allomorph, a nonce word task ('wug test', Berko, 1958) was run as a judgement task. The result, as predicted by the analysis in §3, is that [õj̃s] was preferred in stressed non-initial syllables, and [ɐ̃w̃s] was preferred in unstressed syllables. In initial syllables, [ɐ̃w̃s] and [ɐ̃j̃s] plurals were preferred over [õj̃s], as predicted by the analysis, but the acceptability of [ɐ̃j̃s] was greater than expected.

We present the details of the experiment in §4.1–§4.4 below. We summarize the findings and compare them to the analytical predictions in §4.5.

4.1 Participants

The participants were recruited online via social networks and word of mouth.

The participants volunteered their time and effort. We analyzed data from the 70 participants who completed the task and self-identified as being at least 18 years old and living in Brazil; the rest of the data was discarded. Of these 70, 60 participants said they were living in the state of São Paulo. Regarding their dialect, 56 people said they speak with a São Paulo accent, either urban or rural. Gender: 37 identified as female, 31 as male, and 2 did not say. The average self-reported age was 33 (range 19–74, median 31).

4.2 Materials

The materials for this experiment were originally created for Rizzato (2017), and had the following structure: a total of 57 nonce nominal paradigms were used, including 13 fillers, 15 iambs, 15 trochees, and 14 monosyllables (one monosyllable was discarded before the experiment was run because it sounded like a brand name). The target items are listed in Appendix B. The example item [ˈpovʊ] 'people' was added as well.

The target items all ended in [ɐ̃w̃], e.g., [ˈbɾɐ̃w̃], and for each, three plurals were created: one with final [ɐ̃w̃s], one with final [ɐ̃j̃s], and one with final [õj̃s], e.g., [ˈbɾɐ̃w̃s], [ˈbɾɐ̃j̃s], [ˈbɾõj̃s].

The fillers and the example item were all disyllables with [o] in the first syllable and [ʊ] in the second, e.g., [ˈsodʊ]. Their three plurals had the stressed vowels [o], [ɔ], [u], e.g., [ˈsodʊs], [ˈsɔdʊs], [ˈsudʊs].

To present the items as masculine singular-plural paradigms, six frames were created. Each frame was made of two sentences. The first sentence ended with a masculine singular determiner (e.g., [ˈesɪ], 'this.masc') followed by the nonce singular. The second sentence ended with a plural determiner (e.g., [ˈoitʊ] 'eight') followed by the nonce plural. The sentences were randomly paired with the items.

A female native speaker of urban São Paulo Portuguese, a 20 year old college student, read the sentences three times in a quiet room. The best token of the three was converted to mp3 format. The recordings were not manipulated in any way and were reported to sound very natural.

4.3 Procedure

The experiment was run online using Experigen (Becker & Levine, 2015), with participants using the device and browser of their choice. The server executed a random selection of 24 items for each participant: six each of monosyllables, iambs, trochees, and disyllabic fillers. The experiment was conducted after ethical approval for research with human participants was granted by the Unicamp ProReitoria Ethics Committee, approved for project number 40681820.0.0000.8142.

Participants were informed that the experiment was related to the Portuguese language, involved invented words, that there were no 'right or wrong answers'. They were told that their participation would be voluntary and anonymous, and that their personal information would be maintained confidential.

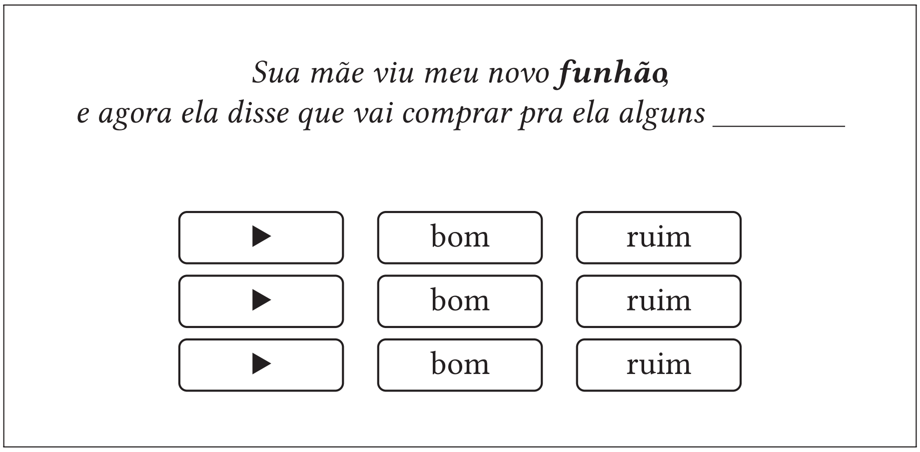

Figure 3: A sample item, presenting the nonce word ⟨funhão⟩ [fũˈɲɐ̃w̃]. Translation of the frame "Your mother saw my$_{\text{M.SG}}$ new$_{\text{M.SG}}$ funhão, and now she says that she will buy herself a few$_{\text{M.PL}}$________". Translation of the buttons: "good", "bad".

In each trial, the frame was shown in Portuguese spelling at the top of the screen, with the singular written, and a blank left for the plural (see **Figure 3**). A first sound button was shown; when it was pressed, the frame was played with one randomly chosen plural. When the audio file was done playing, two buttons appeared, "bom" and "ruim" ("good" and "bad"). Once one of these two was pressed, both buttons were disabled, and participants were led through the same combination of one sound button and two judgment buttons for the second randomly chosen plural, followed by the third plural. A sample trial is shown in **Figure 3**. The sound buttons were not disabled, so participants were free to hear the sounds again, but not change any previous responses. Once the third plural was judged, the experiment moved to the next trial.

The first trial was always the example item [ˈpovʊ], after which the 24 randomly chosen items were presented. At the end of the experiment, participants were asked to provide demographic information as described above.

Rizzato (2017) conducted an experiment that uses the same materials that are used here, but with a different procedure: all three plurals were presented first, and then participants were asked to choose the best of the three. In contrast, the procedure we use here allows each plural to be judged individually as soon as it is heard.

4.4 Results

Participants mostly accepted only one of the three plurals for a given item (53%), but sometimes accepted two plurals (35%), bringing the informative trials to 88% of the total. In the uninformative trials, participants accepted all three plurals for a given item (10% overall, 14% for monosyllables, 7% for iambs, 9% for trochees) or rejected all three (2% overall, 2% for monosyllables, <1% for iambs, 4% for trochees). The raw results are available at https://becker.phonologist.org/projects/bpnasal/, and the results by item are listed in Appendix B.

No outliers were found among the items or the participants. Shapiro-Wilk tests confirmed that the distribution of the responses was not significantly different from normal either by item or by participant.

The results are presented in **Figure 4**. Overall, the participants' preferences reflected the lexicon, especially for the iambs and trochees. The preferences are strongest with iambs, where [õȷ̃s] plurals were the most acceptable at 95% vs. 24% for the other two plurals. For trochees, [ɐ̃w̃s] plurals were most acceptable at 79% vs. 34% for the other two plurals.

As for the monosyllables, the unattested [õȷ̃s] was least acceptable at 47%, as expected. But the [ɐ̃w̃s] and [ɐ̃ȷ̃s] plurals did not follow the lexicon exactly: the highest type frequency [ɐ̃w̃s] was accepted at 58%, but the lower type frequency [ɐ̃ȷ̃s] was accepted slightly more often at 62%. As for the statistical significance of̃ the these results, one must proceed with caution: when a participant provides three judgments for a given item, these three judgments are not completely independent, and thus the number of degrees of freedom is hard to determine. According to t-tests fitted to the monosyllables, [õȷ̃s] plurals are significantly less acceptable than [ɐ̃w̃s] and [ɐ̃ȷ̃s] plurals, but [ɐ̃w̃s] and [ɐ̃ȷ̃s] plurals are not significantly different from each other; these results need to be considered with caution given the aforementioned question about assessing the degrees of freedom.

The results we present here are very similar to the ones in Rizzato (2017). Recall that Rizzato used the same items we used here, but required participants to choose one of three plurals as best. In contrast, we allowed participants to endorse or dismiss each of the three plurals separately. There was no difference to speak of in the treatment of polysyllables between the two experiments. As for the monosyllables, in both experiments, [ɐ̃ȷ̃s] was preferred over [õȷ̃s], but there was a difference in the treatment of [ɐ̃w̃s]: in our experiment, [ɐ̃w̃s] was chosen almost as often as [ɐ̃ȷ̃s], while in Rizzato's experiment, [ɐ̃w̃s] was chosen rarely, even more rarely than [õȷ̃s] (the exact numbers are given in Appendix B). Our results are closer to the observed trend in the lexicon, suggesting perhaps that our methodology allowed speakers to use their grammars more accurately.

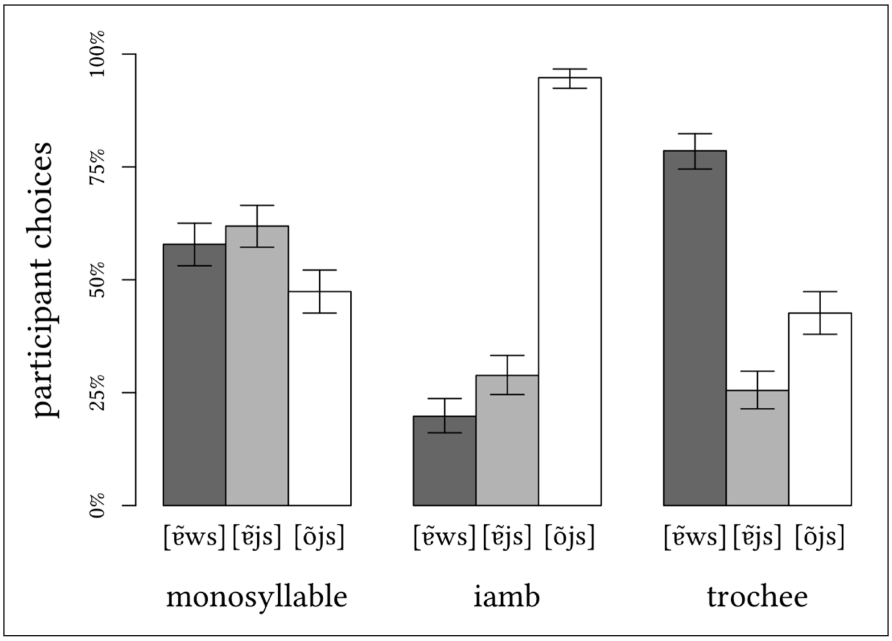

Figure 4: Two-way forced judgements of each of the three plurals ($n = 70$); bars represent 95% confidence intervals, or 1.96 standard errors.

4.5 Discussion

The plural forms of [ɐ̃w̃]-final nouns depend on prosodic context, as predicted by the analysis: the default [õj̃s] is strongly preferred with iambs. The [õj̃s] plural is blocked in trochees due to the limitation of [ɐ̃j̃s] and [õj̃s] to the stressed syllable, leaving [ɐ̃w̃s] as the best option. In monosyllables, initial syllable faithfulness disfavors [õj̃s] and prefers [ɐ̃w̃s], but the acceptability of [ɐ̃j̃s] turned out to be greater than predicted by the analysis.

The results are squarely in favor of a grammar that learns the plurals of existing items using phonological factors, as predicted by the proposed analysis, and confirming the intuitions of Abaurre-Gnerre (1983). The empirical observations show the insufficiency of lexicon-only approaches that encode individual lexical items without prosodic generalizations, and thus fail to derive the observed productive effect of monosyllabicity and stress.

To quantify the predictive power of the analysis, we measured the correlation between the numerical predictions of the analysis with the participants' choices. For the nasal glide, we use our own experimental results, and for the oral glide, we use the results from Becker et al. (2017). The result is shown in **Figure 5**, where the overall correlation between the predictions and the observations is strong and highly significant (Spearman's rank correlation $\rho = .82$, $p < .001$) overall. The correlation is strong and significant for the nasal glide ($\rho = .87$, $p < .005$) and the oral glide ($\rho = .72$, $p < .05$) individually. The acceptability rates and model predictions that were employed in these calculations are given in Appendix A. It is likely that the predictions could be improved by further adjustment of the model; we hope that this paper serves as an invitation for more accurate future quantitative analyses.

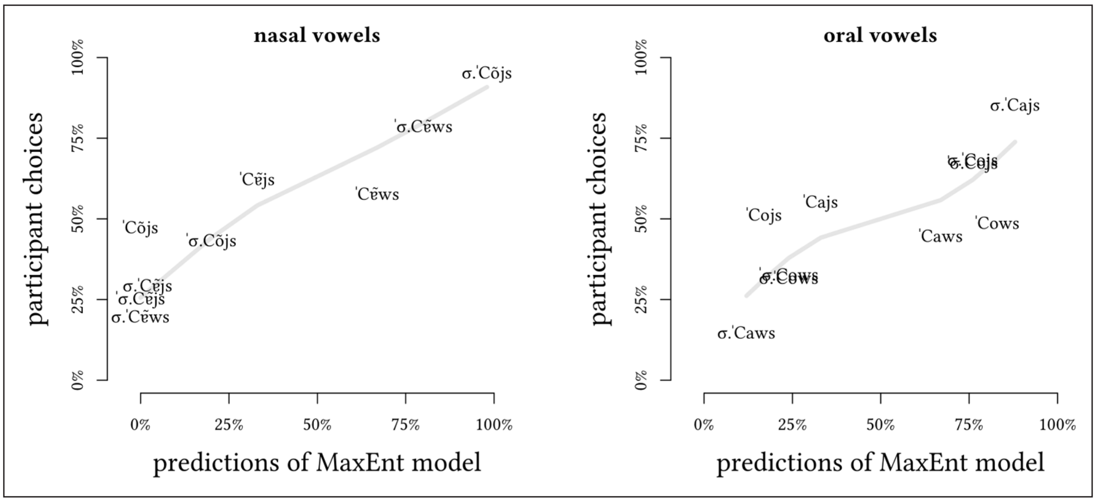

Figure 5: Strong correlation (ρ = .82) between the lexicon-trained analytical predictions and the participant choices, by condition. For the oral vowels, [a] represents lax vowels and [o] represents tense vowels.

5. Conclusions and Directions for Further Research

When it comes to nasal diphthongal plurals, individual items exhibit variable plural forms (Huback, 2007; Pimenta, 2019), but their distribution is not arbitrary; prosodic factors partially predict the plural form. This paper strengthens the position of Abaurre-Gnerre (1983), pointing out the insufficiency of correctly deriving individual lexical items. Providing different underlying representations for the [ẽw̃] of [boˈtẽw̃] 'button' and the [ẽw̃] of [ˈpẽw̃] 'bread' can correctly derive the plurals [boˈtõj̃s] and [ˈpẽj̃s], but without a mechanism for generalizing these patterns, the analysis will fail to correctly derive different plurals for novel monosyllables and novel polysyllables.

In the analysis we provide, it is necessary that all [ẽw̃]-final items have the same surface-true underlying representation /ẽw̃/ for the diphthong. The reason is our reliance on the weights of faithfulness constraints: we use *FLOP-σ1(round) to block [õj̃s] plurals in monosyllables, and that assumes an underlyingly unrounded vowel /ẽ/ that surfaces unfaithfully rounded in [õj̃s] plurals. The uniformity of the underlying representations is ensured by a simple principle: by default, the underlying representation is identical to the singular base (Albright, 2002a,b; Becker, 2009; Hayes, 1995). When [ẽw̃]-final singulars with their different plurals all have the same underlying representation, the differences in observed plurals can only be captured by the grammar, correctly allowing general prosodic principles to partially predict the patterns.

One theoretical consideration left open by our methodology involves the possibilities introduced by speakers who pluralize the definite article but leave the noun itself without a plural suffix, e.g., [ʊz boˈtɐ̃w̃] 'the.pl button'. In our experiment, such forms were not provided as options for nonce items. While the omission of plural morphology on the noun is often considered a matter of morphosyntax in Brazilian Portuguese (Naro & Scherre, 2003), it is intriguing to consider a grammatical model in which unpluralized nouns compete as candidates with the varying diphthongal plurals, and indeed, one might expect a preference for unpluralized nouns even more in monosyllables, as it provides an output that doesn't violate any of the competing faithfulness constraints, and thus doesn't require choosing between [õj̃s], [ɐ̃j̃s], and [ɐ̃w̃s]. Further research to investigate this question would necessitate models with the direct participation of interface constraints that require realization of the plural together with the purely phonological constraints adopted above.

Recall that in our results, we showed that the preferred plural for [ɐ̃w̃]-final singulars depends on synchronic prosodic profiles (stress and monosyllabicity), regardless of the Latin etymology. For iambs, the default [õj̃s] emerges as the plural that maintains the input [round] feature. For trochees, other unstressed nasal diphthongs are banned, leaving [ɐ̃w̃s] as the only option. For monosyllables, the stem vowel is protected from rounding, and we observe a latent preference for the ideally dispersed diphthong [ɐ̃j̃] over the less dispersed [ɐ̃w̃]. Before we conclude, we explore two possible explanations for the preference for monosyllabic [ɐ̃j̃s] plurals: vertical dispersion of diphthongs, and token frequency.

While acoustic measurements of the diphthongs [ɐ̃j̃] and [ɐ̃w̃] are not available in the literature, it is well-established that high back vocoids are phonetically lower than their front counterparts. Thus, Escudero et al. (2009) find that [i] is higher than [u], and Demasi (2009) finds that the [j̃] of [ẽj̃] is higher than the [w̃] of [ɐ̃w̃], providing indirect support for the view that [ɐ̃j̃] is steeper than [ɐ̃w̃]. There is a clear need for continued explorations of the role of diphthong dispersion in perception and in statistical preferences with effects on variation and change.

To formalize the phonetic preference for [ɐ̃j̃] over [ɐ̃w̃] or [õj̃], and thus to model the divergence between the lexicon and the nonce words among the monosyllables, we ran a MaxEnt model with a constraint *ShallowNasalDiph, parallel to *ShallowDiphthong. Since the lexical statistics show no preference for [ɐ̃j̃], we included a prior that forced this constraint to reach a weight of 1 despite the lexical statistics. We followed White's (2017) formal mechanism for incorporating markedness pressures into MaxEnt models; in his implementation, constraints have an analyst-provided target weight (μ), and deviation from it is penalized. The resulting analysis predicted equal acceptability for [ɐ̃j̃s] and [ɐ̃w̃s] in monosyllables, achieving a better fit to the participants' preferences. However, the same model reduced the weight of Max-σ1(round), thus making the predictions for oral monosyllables a little worse. In our analysis, both oral and nasal plurals are unified in their sensitivity to Max-σ1(round), and thus the predictions for nasal diphthongs and oral diphthong are tied together. We conclude that adding *ShallowNasalDiph does not uniformly improve the model, pointing to the necessity of further investigation of the phonetic profiles of Portuguese diphthongs, especially the nasal ones.

A second possible factor in the treatment of monosyllables is token frequency. In the Tang corpus (Tang et al. 2013), there are two [ẽj̃s] plurals, both highly frequent (mean log token frequency 6.5) and six [ẽw̃s] plurals, that cover a range of frequencies with a lower mean (mean log token frequency 4.7). If indeed high token frequency leads to more generalization, this could explain the surprisingly high acceptability of monosyllabic [ẽw̃s] plurals. While most researchers agree that token frequency does not influence the treatment of nonce words in paradigm-oriented tasks (see Albright & Hayes, 2003), perhaps token frequency effects emerge in cases like ours, where the number of types is very low. Factors such as neighborhood density are also a potential realm of future investigation in the study of nasal diphthong alternations that we have left open here.

Despite the remaining challenges, we are encouraged by the success of the MaxEnt model, and its litany of desirable traits. First, the model correctly matches the attested plural(s) for any given existing item by flexibly combining general constraints with lexically-specific versions of these constraints, e.g., Max(round)-sidadẽw̃, ensuring no loss of accuracy relative to lexicon-only analyses. More importantly, however, the model uses constraints with broad applicability in Brazilian Portuguese and cross-linguistically. In particular, this model captures the three broad principles that guide the choice of plurals in Brazilian Portuguese: monosyllabicity, stress (in this case, relevant for the nasal diphthongs), and vertical dispersion (with a decisive role for oral diphthongs and a lesser role for nasal diphthongs). Perhaps most importantly in terms of considering the acquisition of such a grammar, this particular analysis methodically unifies the treatment of oral and nasal diphthongs: constraints on vowel preservation of the suffixal front vowel and on preservation of the feature [round] exert force equally in the alternations of oral and nasal diphthongs.

A Analysis overview

For nasal vowels, corpus type frequencies are based on the Tang corpus (Tang et al. 2013), and nonce word ratios come from the experiment in §4. For oral vowels, corpus type frequencies are from Becker et al. (2017), and nonce word ratios come from experiment 5 of Becker et al. (2017).

The MaxEnt Tool (Hayes & Wilson 2008) was provided with the corpus type frequencies and the constraints and their violations, and it generated the constraint weights and the predicted acceptability of each kind of plural.

V	shape	SG	PL	type frequency	% in the lexicon	MAX-V	MAX (round)	MAX-σ1 (round)	*FLOP (round)	*FLOP-σ1 (round)	LIC-õȷ̃/ˈσ	LIC-ẽȷ̃/ˈσ	*SHALLOWDIPHTHONG	H	prediction	nonce words
						5.89	3.93	2.69	0	15.64	7.28	11.72	0.83			
nasal	mono	ˈfẽw̃	ˈfẽw̃s	6	75%	1								−5.89	67%	58%
			ˈfẽȷ̃s	2	25%		1	1						−6.62	33%	62%
			ˈfõȷ̃s	0	0%				1	1				−15.64	0%	47%
	iamb	taˈgẽw̃	taˈgẽw̃s	16	1%	1								−5.89	0%	20%
			taˈgẽȷ̃s	12	1%		1							−3.93	2%	29%
			taˈgõȷ̃s	1255	98%				1					0	98%	95%
	troch	ˈfɔbẽw̃	ˈfɔbẽw̃s	4	80%	1								−5.89	80%	79%
			ˈfɔbẽȷ̃s	0	0%		1					1		−15.66	0%	25%
			ˈfɔbõȷ̃s	1	20%				1		1			−7.28	20%	43%
lax	mono	ˈbrɔw	ˈbrɔws	11.8	59%	1								−5.89	67%	45%
			ˈbrɔjs	8.2	41%		1	1						−6.62	33%	55%
	iamb	priˈzɛw	priˈzɛws	21.04	8%	1								−5.89	12%	15%
			priˈzɛjs	241.96	92%		1							−3.93	88%	85%
tense	mono	ˈgrew	ˈgrews	11	92%	1								−5.89	83%	49%
			ˈgrejs	1	8%		1	1					1	−7.45	17%	51%
	iamb	suˈpew	suˈpews	19.35	43%	1								−5.89	24%	32%
			suˈpejs	25.65	57%		1						1	−4.76	76%	68%
	troch	ˈɦosew	ˈɦosews	2	4%	1								−5.89	24%	33%
			ˈɦosejs	45	96%		1						1	−4.76	76%	67%

B Experimental results by item

shape	spelling	IPA	Rizzato (2017) (n = 92)			Experiment (n = 70)		
			ɐ̃w̃s	ɐ̃j̃s	õj̃s	ɐ̃w̃s	ɐ̃j̃s	õj̃s
monosyllabic	blão	ˈblɐ̃w̃	.12	.49	.40	.62	.52	.67
	brão	ˈbɾɐ̃w̃	.26	.44	.31	.74	.52	.70
	drão	ˈdɾɐ̃w̃	.46	.26	.29	.62	.38	.58
	fão	ˈfɐ̃w̃	.24	.54	.22	.48	.76	.19
	flão	ˈflɐ̃w̃	.22	.47	.31	.40	.72	.48
	frão	ˈfɾɐ̃w̃	.19	.33	.49	.52	.59	.62
	gão	ˈgɐ̃w̃	.31	.45	.24	.70	.67	.10
	glão	ˈglɐ̃w̃	.35	.21	.44	.62	.41	.66
	klão	ˈklɐ̃w̃	.22	.70	.08	.52	.78	.30
	krão	ˈkɾɐ̃w̃	.37	.42	.21	.62	.78	.41
	plão	ˈplɐ̃w̃	.14	.65	.22	.42	.81	.58
	prão	ˈpɾɐ̃w̃	.14	.73	.12	.44	.81	.26
	trão	ˈtɾɐ̃w̃	.21	.38	.41	.51	.63	.54
	vrão	ˈvɾɐ̃w̃	.28	.21	.51	.76	.48	.59
iamb	bladão	blaˈdɐ̃w̃	.03	0	.97	.35	.26	.94
	majão	maˈʒɐ̃w̃	.06	.11	.83	.17	.40	.93
	tagão	taˈgɐ̃w̃	.10	.10	.81	.25	.29	1.00
	fescão	fesˈkɐ̃w̃	.03	.06	.90	.17	.52	.90
	jetão	ʒeˈtɐ̃w̃	.05	.05	.90	.14	.05	1.00
	nedão	neˈdɐ̃w̃	.03	.03	.94	.14	.27	.95
	crinhão	kɾĩˈɲɐ̃w̃	.11	.03	.86	.19	.42	.96
	gridão	gɾiˈdɐ̃w̃	.05	.02	.93	.20	.15	.90
	quijão	kiˈʒɐ̃w̃	.08	.11	.82	.19	.29	1.00
	bozão	boˈzɐ̃w̃	.03	.11	.86	.07	.15	1.00
	dofão	doˈfɐ̃w̃	.08	.05	.87	.32	.52	.71
	norão	noˈɾɐ̃w̃	0	.05	.95	.16	.28	1.00
	funhão	fũˈɲɐ̃w̃	.05	0	.95	.25	.08	1.00
	surão	suˈɾɐ̃w̃	.02	.13	.85	.21	.21	1.00
	trupão	tɾuˈpɐ̃w̃	.05	.22	.73	.08	.32	.92

(Contd.)

shape	spelling	IPA	Rizzato (2017) (n = 92)			Experiment (n = 70)		
			ɐ̃w̃s	ɐ̃j̃s	õj̃s	ɐ̃w̃s	ɐ̃j̃s	õj̃s
trochee	bádão	ˈbadɐ̃w̃	.47	.17	.36	.78	.28	.53
	gládão	ˈgladɐ̃w̃	.53	.18	.29	.77	.32	.48
	sájão	ˈsaʒɐ̃w̃	.61	.19	.19	.65	.30	.57
	tázão	ˈtazɐ̃w̃	.49	.22	.30	.71	.38	.42
	vádão	ˈvadɐ̃w̃	.51	.24	.24	.86	.32	.36
	kréjão	ˈkɾɛʒɐ̃w̃	.46	.11	.43	.81	.23	.54
	mébão	ˈmɛbɐ̃w̃	.53	.16	.31	.76	.39	.30
	pétão	ˈpɛtɐ̃w̃	.41	.28	.31	.71	.19	.35
	rérão	ˈɦɛɾɐ̃w̃	.71	.06	.24	.90	.17	.37
	téjão	ˈtɛʒɐ̃w̃	.42	.09	.48	.69	.21	.59
	bóvão	ˈbɔvɐ̃w̃	.71	.20	.10	.88	.20	.44
	dóbão	ˈdɔbɐ̃w̃	.69	.20	.11	.83	.12	.25
	dórão	ˈdɔɾɐ̃w̃	.73	.16	.11	.71	.24	.38
	fóbão	ˈfɔbɐ̃w̃	.55	.18	.26	.83	.41	.41
	pródão	ˈpɾɔdɐ̃w̃	.76	.10	.15	.77	.05	.41

Competing Interests

The authors have no competing interests to declare.

References

Abaurre-Gnerre, B. (1983). Alguns casos de formação de plural em português: Uma abordagem natural [Some cases of plural formation in Portuguese: A natural approach]. *Cadernos de Estudos Lingüisticos, 5*, 127–156.

Albright, A. (2002a). *The identification of bases in morphological paradigms*. [Unpublished doctoral dissertation]. UCLA.

Albright, A. (2002b). The lexical bases of morphological well-formedness. In S. Bendjaballah, W. U. Dressler, O. E. Pfeiffer & M. Voeikova (Eds.), *Morphology 2000: Selected papers from the 9th morphology meeting* (pp. 1-8), Vienna, 24-28 February 2000. John Benjamins. DOI: https://doi.org/10.1075/cilt.218.02alb

Albright, A., & Hayes, B. (2003). Rules vs. analogy in English past tenses: A computational/experimental study. *Cognition, 90*, 119–161. DOI: https://doi.org/10.1016/S0010-0277(03)00146-X

Barnes, J. (2006). *Strength and weakness at the interface: Positional neutralization in phonetics and phonology*. Berlin/New York: Mouton de Gruyter. DOI: https://doi.org/10.1515/9783110197617

Becker, M. (2009). *Phonological trends in the lexicon: The role of constraints*. [Unpublished doctoral dissertation]. University of Massachusetts Amherst.

Becker, M., Clemens, L. E., & Nevins, A. (2017). Generalization of French and Portuguese plural alternations and initial syllable protection. *Natural Language and Linguistic Theory, 35*(2), 299–345. Available at Lingbuzz: http://ling.auf.net/lingbuzz/001336. DOI: https://doi.org/10.1007/s11049-016-9343-y

Becker, M., Ketrez, N., & Nevins, A. (2011). The surfeit of the stimulus: Analytic biases filter lexical statistics in Turkish laryngeal alternations. *Language, 87*(1), 84–125. DOI: https://doi.org/10.1353/lan.2011.0016

Becker, M., & Levine, J. (2015). *Experigen – An online experiment platform*. Available at https://github.com/tlozoot/experigen.

Becker, M., Nevins, A., & Levine, J. (2012). Asymmetries in generalizing alternations to and from initial syllables. *Language, 88*(2), 231–268. DOI: https://doi.org/10.1353/lan.2012.0049

Becker, M., Nevins, A., Sandalo, F., & Rizzato, É. (2018). The acquisition path of [w]-final plurals in Brazilian Portuguese. *Journal of Portuguese Linguistics, 17*(1), 4. DOI: https://doi.org/10.5334/jpl.189

Beckman, J. (1997). Positional faithfulness, positional neutralisation and Shona vowel harmony. *Phonology, 14*, 1–46. DOI: https://doi.org/10.1017/S0952675797003308

Beckman, J. (1998). *Positional Faithfulness*. [Unpublished doctoral dissertation]. University of Massachusetts Amherst.

Berko, J. (1958). The child's learning of English morphology. *Word, 14*, 150–177. DOI: https://doi.org/10.1080/00437956.1958.11659661

Bopp da Silva, T. (2005). *A redução da nasalidade em ditongos de sílaba átona em final de vocábulo entre falantes bilíngües e monolíngües do Rio Grande do Sul* [Reduction of nasality in word-final unstressed diphthongs among bilingual and monolingual speakers in Rio Grande do Sul]. [Unpublished master dissertation]. Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil.

Bybee, J., & Slobin, D. (1982). Rules and schemas in the development and use of the English past tense. *Language, 58*, 265–289. DOI: https://doi.org/10.2307/414099

Casali, R. (1998). *Resolving Hiatus*. Garland, New York.

Collischonn, G., & Quednau, L. (2009). As laterais variáveis da região sul [The variable laterals of the southern region]. In L. Bisol & G. Collischonn (Eds.), *Português do sul do brasil: Variação fonológica* (pp. 154–176). Porto Alegre: EDIPUCRS.

Demasi, R. de C. (2009). *A ditongação nasal no português brasileiro: Uma análise acústico-aerodinâmica da fala* [Nasal diphthongization in Brazilian Portuguese: An acoustic-aerodynamic analysis of speech]. [Unpublished master dissertation]. Universidade de São Paulo, Brazil. DOI: https://doi.org/10.11606/D.8.2010.tde-15032010-123909

D'Oliveyra, F. (1536). *Grammatica da lingoagem portuguesa* [A grammar of the Portuguese language]. Lisboa.

Eberle, L. (2022). *Monotongação, ditongação e resolução de hiatos* [Monophthongization, diphthongization and hiatus resolution]. [Unpublished master dissertation]. Universidade Estadual de Campinas, Brazil.

Escudero, P., Paul, B., Rauber, A., & Bion, R. (2009). A crossdialect acoustic description of vowels: Brazilian and European Portuguese. *Journal of the Acoustical Society of America, 126*(3), 1379–1393. DOI: https://doi.org/10.1121/1.3180321

Freitas, M. J. (2001). Sons de ataque: Segmentos complexos, grupos segmentais e representações fonológicas na aquisição do português europeu [Onset sounds: Complex segments, segment groups and phonological representations in the acquisition of European Portuguese]. *Letras de Hoje, 36*(3), 67–84.

Goldwater, S., & Johnson, M. (2003). Learning OT constraint rankings using a maximum entropy model. In J. Spenader, A. Eriksson & O. Dahl (Eds.), *Proceedings of the Stockholm Workshop on Variation within Optimality Theory* (pp. 111–120).

Gomes, C. A., & Gonçalves Manoel, C. (2010). Flexão de número na gramática de criança e na gramática do adulto [Number marking in child grammar and adult grammar]. *Veredas, 14*(1), 122–134.

Hayes, B. (1995). On what to teach the undergraduates: Some changing orthodoxies in phonological theory. In I.-H. Lee (Ed.), *Linguistics in the morning calm, 3*, 59–77. Seoul: Hanshin.

Hayes, B., & Wilson, C. (2008). A maximum entropy model of phonotactics and phonotactic learning. *Linguistic Inquiry, 39*(3), 379–440. DOI: https://doi.org/10.1162/ling.2008.39.3.379

Huback, A. P. (2007). Efeitos de freqüência nas representações mentais [Frequency effects in mental representations]. [Unpublished doctoral dissertation]. Universidade Federal de Minas Gerais, Brazil.

Huback, A. P. (2010). Plurais em -ão do português brasileiro: Efeitos de frequência [Brazilian Portegese ão plurals: Frequency effects]. *Revista Linguística, 6*(1), 9–28. DOI: https://doi.org/10.5380/rabl.v9i1.52337

Huback, A. P. (2011). Irregular plurals in Brazilian Portuguese: An exemplar model approach. *Language Variation and Change, 23*, 245–256. DOI: https://doi.org/10.1017/S0954394511000068

Jesney, K. (2011). Positional faithfulness, non-locality, and the harmonic serialism solution. In S. Lima, K. Mullin & B. Smith (Eds.), *Proceedings of the 39th Meeting of the North East Linguistic Society* (pp. 403–416). GLSA.

Kawasaki, H. (1982). *An acoustical basis for universal constraints on sound sequences*. [Unpublished doctoral dissertation]. University of California, Berkeley.

Kubozono, H. (2001). On the markedness of diphthongs. *Kobe papers in linguistics, 3*, 60–73.

Mateus, M. H., & d'Andrade, E. (2000). *The phonology of Portuguese*. Oxford University Press. DOI: https://doi.org/10.1093/oso/9780198235811.001.0001

Mattoso Câmara, J. (1953). Para o estudo da fonêmica Portuguesa [Towards the study of Portuguese phonemics]. Rio de Janeiro: Simões.

McCarthy, J. J. (2003). OT constraints are categorical. *Phonology, 20*, 75–138. DOI: https://doi.org/10.1017/S0952675703004470

McCarthy, J. J., & Prince, A. (1995). Faithfulness and reduplicative identity. In J. N. Beckman, L. Walsh & S. Urbanczyk (Eds.), *Papers in optimality theory (University of Massachusetts Occasional Papers 18)* (pp. 249–384). University of Massachusetts Amherst: UMOP.

Medeiros, S., Braga, L., & Oliveira, F. (2021). A redução dos ditongos nasais átonos em Cachoeirinha – PE [Nasal diphthong reduction in Cachoeirinha – PE]. *Revista SOCIODIALETO, 11*(33), 1–26. DOI: https://doi.org/10.48211/sociodialeto.v11i33.340

Menn, L., & Ratner, N. B. (1999). *Methods for studying language production*. Psychology Press. DOI: https://doi.org/10.4324/9781410601599

Minkova, D., & Stockwell, R. (2003). English vowel shifts and 'optimal' diphthongs: Is there a logical link? In E. Holt (Ed.), *Optimality Theory and language change* (pp. 169–190). DOI: https://doi.org/10.1007/978-94-010-0195-3_7

Moore-Cantwell, C. (2017). Concurrent learning of the lexicon and phonology. Talk given at *LSA 2017*.

Moore-Cantwell, C., & Pater, J. (2016). Gradient exceptionality in Maximum Entropy grammar with lexically specific constraints. *Catalan Journal of Linguistics, 15*, 53–66. DOI: https://doi.org/10.5565/rev/catjl.183

Morales-Front, A., & Holt, D. E. (1997). On the interplay of morphology, prosody and faithfulness in Portuguese pluralization. In F. MartínezGil & A. Morales-Front (Eds.), *Issues in the phonology and morphology of the major Iberian languages* (pp. 393–437). Washington, DC: Georgetown University Press.

Naro, A. J., & Scherre, M. (2003). Estabilidade e mudança lingüística em tempo real: A concordância de número [Linguistics stability and change in real time: Number agreement]. In M. C. Aiva & M. E. L. Duarte (Eds.), *Mudança lingüística em tempo real*, vol. 1 (pp. 47–62). Contra Capa.

Nevins, A. (2012). Vowel lenition and fortition in Brazilian Portuguese. *Letras de Hoje, 47*(3), 228–233.

Nevins, A. (2015). Natalie Operstein (2010). Consonant structure and prevocalization. (Current Issues in Linguistic Theory 312.) Amsterdam & Philadelphia: John Benjamins Publishing Company. pp. x + 234. *Phonology, 32*(2), 307–317. DOI: https://doi.org/10.1017/S0952675715000172

Pater, J., Staubs, R., Jesney, K., & Smith, B. (2012). Learning probabilities over underlying representations. In *Proceedings of the twelfth meeting of ACLSIGMORPHON: Computational research in phonetics, phonology, and morphology. Learning probabilities over underlying representations*.

Pimenta, H. (2019). *Nasalité et syllabe: Une étude synchronique, diachronique et dialectologique du portugais européen* [Nasality and the syllable: A synchronic, diachronic and dialectological study of European Portuguese] [Unpublished doctoral dissertation]. Université Paris 8, France.

Prince, A., & Smolensky, P. (1993/2004). *Optimality Theory: Constraint interaction in generative grammar*. Oxford: Blackwell. DOI: https://doi.org/10.1002/9780470759400

Rizzato, É. (2017). *Plural de ão e aumentativo zão: Interação das marcas em compostos do português brasileiro* [The plural ão and augmentative zão: The interaction of markers in Brazilian Portuguese compounds]. [Unpublished master dissertation]. Universidade Estadual de Campinas, Brazil.

Schwindt, L. C. (2021). Underlying representation of [w]-final words in Brazilian Portuguese: Evidence from morphological derivation. *Acta Linguistica Academica, 68*(1–2), 139–157. DOI: https://doi.org/10.1556/2062.2021.00482

Schwindt, L. C., & Abaurre, M. B. (2022). On the emergence of [n] in the derivation of nasal-final words in Brazilian Portuguese. *Journal of Speech Sciences, 11*. DOI: https://doi.org/10.20396/joss.v11i00.16537

Schwindt, L. C., & da Silva, T. B. (2009). Panorama da redução da nasalidade em ditongos átonos finais no português do sul do Brasil [A panorama of nasality reduction in final unstressed diphthongs in the Portuguese of the south of Brazi]. In L. Bisol (Ed.), *Português do sul do Brasil: Variação fonológica* (pp. 13–33). Porto Alegre: EDIPUCRS.

Schwindt, L. C., Gaggiola, P. E., & Petry, I. P. (2020). Frequency and distribution of irregular plurals in the Corpus Brasileiro. *Revista de Estudos da Linguagem, 29*(2), 1289-1324. DOI: https://doi.org/10.17851/2237-2083.29.2.1289-1324

Schwindt, L. C., & Wetzels, W. L. (2016). The morphology and phonology of inflection. In W. L. Wetzels, J. Costa & S. Menuzzi (Eds.), *The handbook of Portuguese linguistics* (pp. 188–209). John Wiley & Sons. DOI: https://doi.org/10.1002/9781118791844.ch11

Smolensky, P., & Legendre, G. (2006). *The harmonic mind: From neural computation to optimality-theoretic grammar*. MIT Press.

Steriade, D. (1994). *Positional neutralization*. Ms., UCLA.

Tang, K., Nevins, A., & Becker, M. (2013). Prosody drives alternations: Evidence from a 51 Million Word Corpus of Brazilian Portuguese. *Poster presented at the Linguistic Society of America Meeting*. Boston MA.

Trubetzkoy, N. (1939). *Grundzüge der phonologie* [Basics of phonology]. Göttingen: Vandenhoeck & Ruprecht.

Vigário, M. (2003). *The prosodic word in European Portuguese*. Berlin: Mouton de Gruyter. DOI: https://doi.org/10.1515/9783110900927

White, J. (2017). Accounting for the learnability of saltation in phonological theory: A maximum entropy model with a P-map bias. *Language, 93*(1), 1–36. DOI: https://doi.org/10.1353/lan.2017.0001

Zuraw, K. (2000). *Patterned exceptions in phonology*. [Unpublished doctoral dissertation]. UCLA.