-(a)licious and -(a)thon: new morphemes obey pre-existing constraints

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Abstract.

This paper argues that the distribution of *-(a)licious* and *-(a)thon* is a result of speakers applying ∗Clash and ∗Hiatus, well-motived constraints in English, to novel suffixes. Both experimental and corpus data show that the form of the suffix, e.g. *-alicious* with schwa or *-licious* without, tends to avoid stress clash and hiatus. The claim that speakers use their existing English phonological grammar for these suffixes is supported in three ways. First, the constraints are attested outside of the suffixes, and behave in similar ways across the suffixes and alternations, e.g. ∗Hiatus is stronger than ∗Clash in both *-(a)licious* suffixation and phonotactics. Second, speakers don't have sufficient evidence to learn the phonological distribution of the suffixes, but agree on novel words in an experiment. Third, the choice of suffix considers the output of the Rhythm Rule, a phonological rule that resolves stress clash by retracting stress. The clash-avoiding variant of the suffix is more likely in words where stress clash can't be avoided through the Rhythm Rule. Taken together, these results provide strong support for a view of morphophonology in which suffix selection is conditioned by language-wide phonological constraints, and prove challenging for analyses in which phonological requirements are memorized on a suffix by suffix basis.

1 Introduction

The English suffix *-(a)licious* has become common in recent years, being featured in music, advertising, and across the internet. The suffix creates adjectives from nouns, as shown in the examples below.

(1) Examples of *-(a)licious*

a. ER's George Clooney and Noah Wyle play two **hunkalicious** M.D.'s whom Monica and Rachel date. (Entertainment Magazine 2001)

b. …embrace our **body-licious** curves. (People Magazine 2007)

A previously unstudied aspect of *-(a)licious* is its phonological conditioning. The suffix has two allomorphs – [əlɪʃɨs] and [lɪʃɨs] – whose distribution is sensitive to the final segment and stress pattern of the root. The schwaful allomorph tends to occur after consonants and stressed syllables (e.g. *hunk-alicious*), while the schwaless allomorph tends to occur after vowels and unstressed syllables (e.g. *body-licious*).

In this paper, I present an analysis of *-(a)licious*, along with the related suffix *-(a)thon*, which obeys similar phonological conditioning. Under my analysis, *-(a)licious* is a case of Phonologically Conditioned Allomorph Selection (PCA: Carstairs 1988 and subsequent work). PCA describes a situation in which there are multiple allomorphs, each with a different Underlying Representation (UR), and the choice of UR is phonologically conditioned. Such an analysis is necessary for *-(a)licious*, because it doesn't lend itself to an analysis with deletion, epenthesis, or blend formation.

(2) PCA in *-(a)licious*

a. Listed URs /əlɪʃɨs/ and /lɪʃɨs/

b. Conditioning: /əlɪʃɨs/ more likely after consonants and stressed syllables
/lɪʃɨs/ more likely after vowels and unstressed syllables

A longstanding question in the analysis of PCA is how to encode phonological conditioning: is it a product of the lexicon, the phonological grammar, or some combination of the two? The grammar-driven approach to PCA is taken in constraint-based frameworks, especially Optimality Theory (OT: Prince and Smolensky 1993/2004). OT accounts of PCA argue that phonological conditioning emerges from the phonological grammar, which has the power to decide between listed URs (Mester 1994; Kager 1996; Mascaró 1996; Wolf 2008). The lexical approach has been argued in the Distributed Morphology literature (DM: Halle and Marantz 1993) and most prominently in Paster (2006). These lexical accounts argue that requirements are listed for every affix, usually as subcategorization frames (see Embick 2010 and references within).

The case of *-(a)licious* is important because it bears on the longstanding debate between the grammatical and lexical approaches. Using corpus and experimental data, I argue that the phonological conditioning of *-(a)licious* and *-(a)thon* is a result of the general phonological grammar. Speakers recruit pre-existing English constraints, like ∗CLASH and HIATUS, to help choose between [əlɪʃɨs] and [lɪʃɨs]. The alternative, which I argue against, is that phonological conditioning is encoded in the lexicon on a suffix-by-suffix basis, independent of the phonological grammar. Although there is no shortage of examples showing that the lexical approach is necessary, as shown in Paster (2006)'s typological survey of PCA, there are fewer examples that necesitate the grammatical approach. *-(a)licious* is one such case.

There are three main arguments for employing the grammatical approach for *-(a)licious* and *-(a)thon*. First, the two suffixes show similar phonological conditioning, observable in both a natural langauge corpus and a judgment experiment. Crucially, this phonological conditioning is consistent with the rest of English phonology and phonotactics, as expected if the same grammar is used for English phonology, phonotactics, and *-(a)licious*. Second, there is sparse data for learners to acquire the conditioning of *-(a)licious*, but subjects agree on its conditioning in a judgment experiment. Finally, allomorphy in *-(a)licious* interacts with the Rhythm Rule. The stress conditioning of *-(a)licious* is sensitive to surface forms, as predicted by the use of a constraint like ∗CLASH.

This paper also provides an account of the experimental data in MaxEnt Harmonic Grammar (Goldwater and Johnson 2003), building on earlier accounts of PCA in OT. In this model, phonological conditioning follows from weighted phonological constraints, and UR selection is evaluated at the same time as phonological processes. A novel contribution of the analysis is UR constraints, constraints which regulate UR selection (see §6.2 for discussion of related precedents). UR constraints provide a means to capture differences between the two suffixes, and also provide a framework in which these differences can be learned using existing learning algorithms.

The paper is organised as follows. In §2, I provide background on *-(a)licious* and *-(a)thon*: their meaning and basic phonological conditioning, along with counts and examples from corpora. This section also shows that there is sparse evidence for learners to acquire the suffixes' distribution. In §3, I present arguments using ∗CLASH and ∗HIATUS to account for the distribution of *-(a)licious* and *-(a)thon*. In §4 and §5, I present the results of an experiment that further tests the claim that PCA is conditioned by markedness constraints. In §4, the experiment tests stems with phonological shapes that are under-attested in the corpus. These stems behave as predicted by the account with ∗HIATUS and ∗CLASH. In §5, I present experimental suggesting evidence that *-(a)licious* is sensitive to the Rhythm Rule, supporting both a parallel model and the use of output-oriented ∗CLASH.

In §6, I present a MaxEnt model of the experimental results. The model of *-(a)licious* and *-(a)thon* can account for both their common phonological conditioning and their differences. The constraint weights from the suffix grammar are mirrored in the distribution of words in the English lexicon, suggesting that the same constraints are active in both suffixation and phonotactics. Finally, in §7, I briefly address non-PCA analyses, arguing that *-(a)licious* cannot straightforwardly be analyzed as epenthesis, deletion, a minor rule, or a blend.

2 Phonological conditioning

This section provides background on *-(a)licious* and *-(a)thon*: their meaning, phonological distribution, and morphological properties. Using data from the corpus GloWbe I show that they pattern in many ways like well-established English suffixes.

2.1 Background and phonological conditioning of -(a)licious

-(a)licious is a productive derivational suffix, which creates adjectives from nouns. Derived adjectives have one of the meanings below.

(3) NOUN-licious (1): Possessing characteristics of NOUN (and this is positive).

(4) NOUN-licious (2): Containing an abundance of NOUN (and this is positive).

While *-(a)licious* selects for nouns, it can also combine with adjectives, e.g. *sexy-licious*. Adjective-derived *-(a)licious* words are less common, and some speakers even find them ungrammatical. In addition, words derived with *-(a)licious* always have a positive connotation. Negative *-(a)licious* words occur very rarely, and perhaps only sarcastically (e.g. *barf-a-licious*).

Here are a few real world examples, taken from the Corpus of Contemporary American English (COCA: Davies 2008-). COCA is a collection of spoken and written English from 1990–2012.

(5) But her new show, ‘Cougar Town’ is stirring up a lot of **cougarlicious** controversy. (CNN Showbiz 2009)

(6) …embrace our **body-licious** curves. (People Magazine 2007)

(7) British Columbian back county skiing: It’s **tree-licious**! (Skiing 2005)

(8) ER’s George Clooney and Noah Wyle play two **hunkalicious** M.D.’s whom Monica and Rachel date. (Entertainment Magazine 2001)

(9) The gourmet concoction, while not much more difficult, is equally **starchilicious**. (Atlanta Journal Constitution 1996)

In these examples, we find both meanings of *-(a)licious*. Back county skiing is *tree-licious* because it’s full of trees (but does not possess characteristics of a tree), while George Clooney is *hunkalicious* because he has the characteristics of a hunk (but is not full of hunks). Some cases, e.g. *starchilicious*, are ambiguous between the two meanings.

One property of *-(a)licious* that has not received attention is its phonological conditioning. In this section, I illustrate the suffix’s distribution with counts from the Corpus of Global Web-Based English (GloWbE: Davies 2013), a 1.9-billion-word corpus representing 20 different English-speaking countries. Since GloWbE is a corpus of web-based English, it includes user names, restaurant names, website names, etc., types of words which lend themselves to formation with *-(a)licious*.

The corpus results show that the suffix is subject to a great deal of optionality. For example, both *babe-licious* and *babe-alicious* are attested. However, this variation is structured, and the distribution of allomorphs is predictable based on both segmental and prosodic factors. The corpus findings are robust, and closely replicated in the experiment later in the paper.

Corpus methods. In the counts that follow, each different stem is counted only once, regardless of its number of tokens. If a stem occurs with both *-alicious* and *-licious*, it’s counted once for each. Given how many items are proper names, token counts for *-(a)licious* and *-(a)thon* in GloWbE are not informative, and most licious-words only occur once in the corpus.

A search for words ending in *licious* yielded 437 different licious-words after initial exclusions.

(10) Initial exclusions:

  a. Typos (e.g. *relicious* for *religious*)
  b. Existing words (e.g. *cilicious*, *silicious*, *delicious*)
  c. Spelling variants (multiple spellings counted only once, e.g. *babe-ilicious, babeolicious, babe-a-licious*)

After the initial exclusions, 127 words were excluded by hand.

(11) The following were excluded:

  a. 50 words with L-final stems (e.g. *xmlicious*, *tentpolicious*)
  b. 30 words treated as blends, where part of the stem isn't present in the *-(a)licious* word (e.g. *Ferg-alicious* from *Fergie*)
  c. 30 words whose stems couldn't be identified given the context (e.g. *vivalicious*, *yumbolicious*, *vogonalicious*)
  d. 17 words with ambiguous stems (e.g. *bellicious* - *bell* or *belly*?)

L-final stems were excluded because they take a third form of the suffix *-icious*, as in *bottle-icious*. It's unclear whether this form results from suppletion or is derived from *-licious* via L-deletion, so I won't discuss it at length here.

After exclusions, 310 different licious-words remain. For each word, the stem is identifiable, complete, unambiguous, and does not end in L. Each stem was hand-coded for part of speech, final stress, final consonant, and number of syllables. In polysyllabic words only final primary stress was counted as final stress.

Prosodic conditioning. Like many derivational suffixes in English, *-(a)licious* is conditioned by the stress pattern of the stem: stems with final stress prefer *-alicious*. This is shown below with some examples from COCA. In examples, I spell the schwaful form as *-alicious*, and indicate my judgments for stress with overset numbers: 1 indicates primary stress, 2 indicates secondary stress, and so on. Unstressed syllables are unnumbered.

$\ldots\acute{\sigma}$-$\underline{\text{a}}$licious	$\ldots\breve{\sigma}$-licious
$\text{c}\overset{2}{\text{u}}\text{rve }\underline{\text{a}}\text{l}\overset{1}{\text{i}}\text{cious}$	$\text{r}\overset{2}{\text{u}}\text{by l}\overset{1}{\text{i}}\text{cious}$
$\text{h}\overset{2}{\text{u}}\text{nk }\underline{\text{a}}\text{l}\overset{1}{\text{i}}\text{cious}$	$\text{t}\overset{2}{\text{u}}\text{rkey l}\overset{1}{\text{i}}\text{cious}$
$\text{st}\overset{2}{\text{a}}\text{rch }\underline{\text{a}}\text{l}\overset{1}{\text{i}}\text{cious}$	$\text{c}\overset{2}{\text{o}}\text{ugar l}\overset{1}{\text{i}}\text{cious}$

Table 1: Effect of stress, examples from COCA

The type of final segment also plays a role. Stems with final consonants prefer *-alicious*, while stems with final vowels prefer *-licious*. This is shown below with more COCA examples.

...C-alicious	....V-licious
curve alicious	tree licious
hunk alicious	jew licious
low carb alicious	ruby licious

Table 2: Effect of final segment, examples from COCA

The table below summarizes the results of the GloWbE search. It shows the proportion of the schwaful allomorph *-alicious* by phonological context. I use the stems *hero*, *café*, *police*, and *cactus* as category exemplars: a police-type stem has final stress and a final consonant, just like *police*. N is the total number of different stems of each type. For example, there are 31 licious-words with stems like *cactus*, with non-final stress and a final consonant.

Stem type	Stress	Final segment	Proportion schwa	N
hero	non-final	vowel	0.00	113
café	final	vowel	0.11	191
cactus	non-final	consonant	0.21	31
police	final	consonant	0.78	147

Table 3: Distribution of licious-words by stem type (N=310)

The table shows effects of both final segment and final stress. Stems ending in consonants take *-alicious* more than stems ending in vowels (compare *cactus* and *hero*), and stems with final stress take *-alicious* more than stems with non-final stress, as long as they match in final segment (compare *cactus* and *police*). Note that cactus-type stems are between hero-type and police-type stems. This follows from the fact that cactus-type stems are subject to competing phonological demands, ending in both a consonant (preferring schwa) and unstressed syllable (dispreferring schwa).

The effects of stress and final segment are independent. As shown below, final segment has an effect after controlling for final stress. Among stems with final stress, C-final stems occur with *-alicious* proportionately more often than V-final stems. For each cell, the proportion out of the total stems is presented in parentheses. The results of a Fisher's exact test are presented in the table captions. Fisher's exact is used here because of the small counts in some cells.

	C-final	V-final
-licious	33 (0.20)	17 (0.10)
-alicious	114 (0.69)	2 (0.01)

Table 4: Final-stressed *-(a)licious* stems: effect of final segment (N=166, p<0.001)

Likewise, stress has an effect after controlling for final segment. Among C-final stems, final-stress stems occur with *-alicious* proportionately more often than non-final-stress stems.

	Final stress	Non-final stress
-licious	33 (0.19)	24 (0.13)
-alicious	114 (0.65)	7 (0.04)

Table 5: C-final *-(a)licious* stems: effect of stress (N=178, p<0.001)

The basic pattern of phonological conditioning re-appears in the corpus results for *-(a)thon* and the experimental results in §4.

2.2 Phonological conditioning of -(a)thon

The suffix *-(a)thon* shares many properties with *-(a)licious*, and I use it as a point of comparison. *-(a)thon* is a derivational suffix, creating nouns from verbs and nouns, with two forms, [θɑn] and [əθɑn]. It can have either meaning below.

(12) X-thon (1): An event that involves repeated instances with X or cases of Xing (X=NOUN or VERB)

(13) X-thon (2): A fundraiser to benefit X (X=NOUN)

The phonological conditioning of *-(a)thon* is similar to that of *-(a)licious*, with effects of final stress and final segment. This is shown in the results of a corpus search, summarized in the table below. The corpus search used the same methods as were used for *-(a)licious*, except L-final stems were included in the analysis.

	Stress	Final segment	Proportion schwa	N
police	final	consonant	0.98	244
cactus	non-final	consonant	0.71	56
café	final	vowel	1.00	7
hero	non-final	vowel	0.24	29

Table 6: Distribution of thon-words by stem type (N=336)

The schwa in *-(a)thon* is most likely in police-type stems, and least likely in hero-type stems. Cactus-type stems are between. Stems like *café* run contrary to the general pattern, possibly due to their rarity. There are only 7 café-type stems in the *-(a)thon* data, and all have a schwa.

The table below shows the effect of stress among C-final stems. Stress-final stems occur with schwa proportionately more often than non-stress-final stems. The results of Fisher's exact test are reported in the caption.

	Final stress	Non-final stress
-thon	5 (0.02)	16 (0.05)
-athon	239 (0.80)	40 (0.13)

Table 7: C-final stems: effect of stress (N=300, p<0.001)

There is also an effect of final segment after controlling for stress and syllable count. Among polysyllabic stems with non-final stress, C-final stems occur with *-athon* proportionately more often than V-final stems.

	C-final	V-final
-thon	16 (0.19)	22 (0.26)
-athon	40 (0.47)	7 (0.08)

Table 8: Non-final-stress stems: effect of final segment (N=85, p<0.001)

2.3 -(a)licious vs. -(a)thon

Although they obey similar phonological conditioning, *-(a)licious* and *-(a)thon* differ in a few important ways. First, *-(a)thon* is more likely to occur with a schwa than *-(a)licious*. This difference holds across all stem types in the corpus. This is shown by the graph below, which compares the corpus results for the two suffixes.

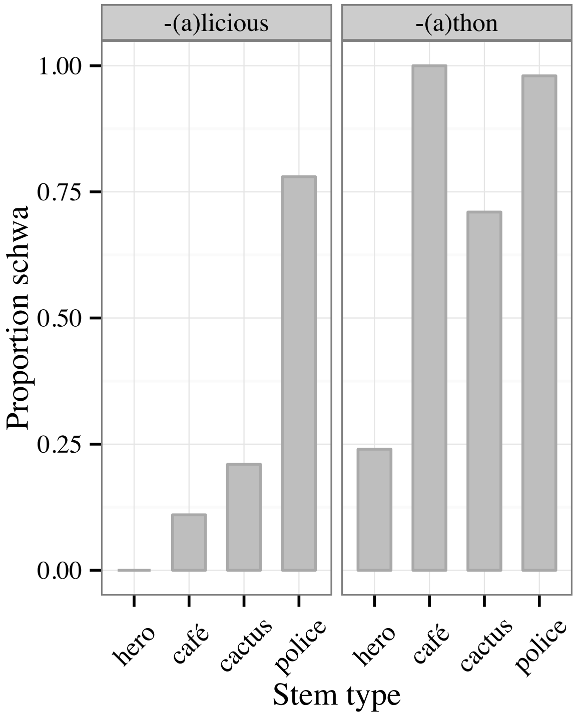

Figure 1: Proportion of stems with -*alicious* (L) and -*athon* (R) in the corpus GlOWbE

The greater preference for schwa in -*(a)thon* appears again in the experiment, in which the difference holds for the vast majority of items and subjects. I treat the difference between -*(a)thon* and -*(a)licious* as an arbitrary property of the suffixes: there's no phonological motivation for the difference. Instead, speakers simply learn that schwa is more likely for -*(a)thon*. This is consistent with the corpus counts, in which the six most frequent thon-words all occur with a schwa, while the six most frequent licious-words occur without one. In §6, I provide a framework that can model these arbitrary tendencies, in addition to the phonological preferences discussed earlier.

The second difference is that -*(a)thon* takes secondary stress in its derived words, while -*(a)licious* takes main stress. This is shown below for the stem *hero*. Judgments for stress are my own, but have been informally confirmed by at least a dozen English speakers.

(14) Stress differences between -*(a)thon* and -*(a)licious*

a. h$\overset{1}{\text{e}}$ro th$\overset{2}{\text{o}}$n
b. h$\overset{2}{\text{e}}$ro l$\overset{1}{\text{i}}$cious

Third, -*(a)thon* is one of many derivational suffixes in English that causes stress to shift rightwards in its stem, while -*(a)licious* does not trigger stress shift. The examples below show -*(a)thon* causing rightwards movement of stress, along with the suffixes -*al*, -*ic*, and -*ity*, all of which exhibit the same behavior.

(15) Examples of stress shift

a.	únderwear	underwéar-athòn
b.	Íceland	Iceland-athòn
c.	cónsonant	consonánt-al
d.	Íceland	Iceland-ic
e.	vírgin	virgín-ity

Stress shift is only possible when V-initial *-athon* is used. Stress shift is impossible with *-thon*.

(16) Examples of stress shift

a.	únderwèar	underwéar-athòn	
b.	únderwèar	únderwear-thòn	*underwéar-thòn
c.	phónème	phonéme-athòn	
d.	phónème	phóneme-thòn	*phonéme-thòn

This suggests that rightwards stress shift provides a means to satisfy the rhythmic requirements of *-(a)thon*. When *-athon* is used, stress shift applies creating a final-stressed root, the type of stem that *-athon* prefers. However, when *-thon* is used, stress shift is impossible, because such a shift would violate the phonological conditioning of the suffix. Beyond these examples, I don't discuss the stress-shifting behavior of *-(a)thon*, but in §5, I present experiment evidence that shows *-(a)licious* interacts with the Rhythm Rule to avoid stress clash in a similar way.

2.4 Related suffixes

Although there is no previous work on the phonological conditioning of *-(a)licious* or *-(a)thon*, many English suffixes follow a similar distribution.

Siegel (1974) describes the suffix *-(e)teria* as subject to the same stress conditioning. Just like *-(a)licious*, the schwaless form of *-(e)teria* tends to occur with final-unstressed stems. In the examples below, stress has been added, and a *(t)* indicates that the *t* is not present in the spelling.

...σ́+.e.teria	...σ̆+teria
c$\overset{2}{\text{a}}$ke et$\overset{1}{\text{e}}$ria	b$\overset{2}{\text{a}}$sket (t)$\overset{1}{\text{e}}$ria
cl$\overset{2}{\text{e}}$an et$\overset{1}{\text{e}}$ria	ch$\overset{2}{\text{o}}$colate (t)$\overset{1}{\text{e}}$ria
h$\overset{2}{\text{a}}$t et$\overset{1}{\text{e}}$ria	c$\overset{2}{\text{a}}$sket (t)$\overset{1}{\text{e}}$ria
f$\overset{2}{\text{u}}$rnit$\overset{3}{\text{u}}$re et$\overset{1}{\text{e}}$ria	c$\overset{2}{\text{a}}$ndy t$\overset{1}{\text{e}}$ria
dr$\overset{2}{\text{y}}$g$\overset{3}{\text{o}}$ods et$\overset{1}{\text{e}}$ria	r$\overset{2}{\text{a}}$dio t$\overset{1}{\text{e}}$ria

Table 9: Siegel (1974): examples of *-teria* and *-eteria*

Beyond *-(e)teria*, many contemporary suffixes follow the same pattern. An informal survey of Wiktionary, an open-source dictionary, suggests that all of the suffixes below are similarly conditioned by stress. For nearly all of the suffixes, the alternating vowel is schwa, although some are occasionally pronounced with [o] (*-orama, -ophile, -onomics*), and *-(ma)geddon* has a CV syllable that alternates.[1]

(17) Alternating libfixes that are similar to *-(a)licious* and *-(a)thon*
-(o)rama
-(i)riffic
-(o)gram
-(a)saurus
-(ma)geddon
-(i)verse
-(a)pedia
-(o)nomics
-(o)phile
-(a)holic
-(i)vore

Well-established derivational suffixes in English obey similar phonological conditioning. For example, the suffix *-(e)ry* has two forms, [əɹi] and [ɹi]: [əɹi] occurs after stressed syllables (*clown-ery*), and [ɹi] after unstressed ones (*comic-ry*). The phonological conditioning of other derivational suffixes is discussed in §3, and even more cases of phonologically-conditioned derivation in English can be found in Raffelsiefen (2004) and Plag (1999).

2.5 Distribution of -(a)licious stems

The discussion of corpus counts for *-(a)licious* is complicated by the fact that the corpus contains an uneven distribution of stems, with a number of stem shapes being underattested. This section considers the distribution of stems in the corpus data, making three main points:

- *-(a)licious* is a productive suffix.
- *-(a)licious* selects for nouns over adjectives and verbs.
- *-(a)licious* is under attested with some stem shapes, especially C-final trochees like *cactus*.

The first two points support the treatment of *-(a)licious* as a productive English suffix. The last point motivates the experiment presented later in the paper and provides support for the grammatical approach to PCA.

Productivity. I use *productivity* here in the sense of Baayen (1992): the propensity of a suffix to be used in the creation of new words. The productivity of *-(a)licious* is evidenced by its large number of hapaxes, words that occur only once in the corpus. The number of hapaxes reflects how often a suffix is used in coining, and factors heavily into numerical measures of productivity. Of all stems (types), more than half are hapaxes, and out of the total number of tokens, more than a fifth are hapaxes.

(18) Hapax, type, and token counts for *-(a)licious*
a. Number of types = 310
b. Number of tokens = 905
c. Number of hapaxes = 182

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[1] A growing list of this type of suffix – sometimes called libfixes – can be found on Arnold Zwicky's blog (http://arnoldzwicky.org/category/morphology/libfixes/). His list includes many of the ones here, along with observations about libfixes in the wild. There are also contemporary suffixes with a single fixed form and no alternating vowel, such as *-gate*, *-tastic*, and *-zilla*. All of these begin with a consonant.

Baayen's (1992) P quantifies an affix's productivity. P is the ratio of the total hapaxes to the number of tokens. The P of *-(a)licious* is 0.201 (P = 182/905). This is high relative to other English affixes: in Hay and Baayen (2002), the only affix with a higher P is *-like*.

Although *-(a)licious* is amenable to coining, there are still a small number of established *-(a)licious* words. The word *booty-licious* occurs 87 times in the corpus (with 3 different spellings), accounting for about 10% of tokens. The six most common *-(a)licious* words are below, listed in descending order of frequency.

(19) Six most common *-(a)licious* words

a. booty-licious
b. diva-licious
c. jersey-licious
d. summer-licious
e. taco-licious
f. yummy-licious

Together, these six words account for over a quarter of *-(a)licious* tokens in the corpus. As mentioned earlier, the fact that the most common licious-words all occur without a schwa, while the most common thon-words occur with a schwa, can account for the differences between *-(a)licious* and *-(a)thon* with respect to schwa preference.

Selectional restrictions. The claim that *-(a)licious* selects for nouns over other syntactic categories finds support in the corpus. As shown in the table below, 78% of stems are nouns or proper nouns.

	Adjective	Noun	Proper Noun	Verb	Unknown
Count	34	195	48	8	25
Proportion	0.11	0.63	0.15	0.03	0.08

Table 10: Distribution of stems across different parts of speech (N=310)

A few notes on the syntactic categories above. Stems were coded by hand. Stems with the syntactic category *Unknown* are ambiguous, e.g. *queer*, *extra*, *nom*. *Queer* can be either an adjective or noun in the attested word *queer-licious*. Color words, which make up a handful of stems, were coded as adjectives.

Phonological properties of stems. Complicating the description in earlier sections, certain stem shapes are under-attested with *-(a)licious*, and the number of syllables in a stem is almost perfectly correlated with stress. Stems are either monosyllables or trochees; only 2% of stems are iambs. In the analysis of the corpus data, then, syllable count and stress are interchangeable as predictors.

	1 syllable	2 syllables
final stress	160 (0.52)	6 (0.02)
non-final stress	N/A	143 (0.46)

Table 11: Distribution of stress and syllable count in *-(a)licious* stems (N=310)

Among licious-words in the corpus, there are no stems greater than two syllables. This gap in the corpus data suggests that the suffix may be sensitive to a size constraint, only combining with bases that are two syllables or shorter. A similar size constraint can be observed in the English comparative *-er*, but no such size constraint is observable for *-(a)thon*, which combines with very long roots in GloWbE (e.g. *procrastination-thon*).

There are also surprisingly few cactus-type stems. Most stems are C-final monosyllables, or V-final trochees.

	C-final	V-final
final stress	147 (0.47)	19 (0.06)
non-final stress	31 (0.10)	113 (0.36)

Table 12: Distribution of final segment and stress in *-(a)licious* stems (N=310)

The lack of *-(a)licious* stems may make learning the suffix's distribution difficult. The majority of stems only occur once in the corpus, and cactus-type stems are additionally rare. Although cactus-type stems are under attested, speakers treat them as expected when they do occur. The 31 cactus-type stems in the corpus demonstrate exactly the phonological conditioning we'd expect given the phonological requirements of *-(a)licious*, and subjects reproduce nearly the same distribution in the experiment.

2.6 Summary of corpus results

There are three main findings from the corpus study. First, *-(a)licious* and *-(a)thon* are used creatively to derive new words. In the corpus, there are over 300 different words with *-(a)licious* and over 300 with *-(a)thon*. The majority of these words only occur once. Second, these suffixes are conditioned both by the final segment and stress pattern of the stem. Third, *-(a)thon* is more likely to occur with a schwa than *-(a)licious* across all phonological contexts. The difference between *-(a)thon* and *-(a)licious* follows from the most frequent words with each suffix. The most frequent *-(a)thon* words contain a schwa, while the most frequent *-(a)licious* words are schwaless.

3 Driven by ∗Clash and ∗Hiatus

Given the distribution of *-(a)licious* and *-(a)thon*, the natural question is where phonological conditioning comes from. I consider two possibilities: conditioning is the result of language-wide constraints (the LWC Hypothesis); or conditioning is the result of subcategorization. Each of these possibilities is sketched below. In this section, I focus on *-(a)licious*, but all of the argumentation applies equally to *-(a)thon*.

(20) The LWC Hypothesis: the distribution of *-(a)licious* is phonologically optimizing. It's the result of English-wide markedness constraints like ∗Clash and ∗Lapse.

(21) Subcategorization: the distribution of *-(a)licious* is the result of phonological subcategorization. The phonological contexts for *-(a)licious* are lexically listed.

The LWC Hypothesis. I argue for such an analysis here, in which three constraints are responsible or *-(a)licious* and *-(a)thon*.

(22) ∗Clash
Assign one violation for every sequence of two stressed syllables.

(23) ∗Lapse
Assign one violation for every sequence of two unstressed syllables.

(24) ∗Hiatus
Assign one violation for every sequence of two vowels.

∗Clash and ∗Lapse capture the generalization that *-(a)licious* optimizes rhythm, avoiding sequences of consecutive stressed or unstressed syllables. In the examples below, forms with alternating rhythm are judged as better than forms with clashes and lapses.

(25) Examples with perfect rhythm

σσ́+σσ́	police-alicious
	police-athon
σ́σ+σ́σ	cactus-licious

(26) Examples with a stress clash or lapse

σσ́+σ́σ	*police-licious
σ́σ+σσ́	?cactus-alicious

∗Hiatus captures the generalization that allomorphy avoids vowel-vowel sequences, as in **hero-alicious* and **hero-athon*. As the experimental results will show, speakers are especially sensitive to hiatus where the first vowel is lax, especially avoiding the schwaful allomorph for stems like *Cuba*. This restriction can be observed throughout English, as discussed below.

Subcategorization. Under the subcategorization account, all phonological conditioning results from subcategorization frames. For example, a subcategorization frame requires *-alicious* to combine with stress-final, consonant-final stems, while *-licious* occurs elsewhere.

(27) *-alicious* ↔ C ___

(28) *-alicious* ↔ σ́ ___

(29) *-licious* elsewhere

Given that these frames are morpheme-specific, language learners must acquire selectional requirements for every suffix.

Differences between the accounts. Under the LWC Hypothesis, phonological constraints on PCA are completely independent of the lexicon. Their effects should emerge regardless of the suffix at hand, and the same constraints should hold outside of suffixation, in phonotactics and alternations.

(30) The LWC Hypothesis is supported when PCA-conditioning constraints are active elsewhere in the same language.
  a. They condition other cases of PCA.
  b. They condition phonotactics.
  c. They condition alternations.

For subcategorization, any resemblance between alternations, phonotactics, and suffixal selectional requirements is a coincidence. Although shared sound change can be used to explain similarities across suffixes, the synchronic grammar encodes each suffix's requirements separately.

The LWC Hypothesis also differs from subcategorization with respect to learnability and cross-suffix similarity. If a speaker recruits the existing phonological grammar to decide between suffixes, they don't need to learn a suffix's particular phonological requirements. Furthermore, under the LWC Hypothesis, no historical explanation is necessary to account for similarity across suffixes, since suffixes are conditioned by the same phonological grammar. Both points are summarized below.

(31) The LWC Hypothesis is also supported when:
  a. There's insufficient data to learn the affix's distribution.
  b. There's no historical explanation for the affix's distribution.

There's one final requirement for any account that assumes language-wide constraints. Since everything follows from a single grammar, there must be some consistent ranking or weighting of constraints for all cases.

(32) Requirement of the LWC Hypothesis
  The constraint hierarchy needed for PCA must be consistent with other aspects of the phonology, including both alternations and phonotactics.

In the account of *-(a)licious* and *-(a)thon* in §8, I show that it's possible to account for the distribution of both suffixes with a single weighting of markedness constraints. Moreover, I show that English phonotactics are consistent with the weights of ∗CLASH, ∗HIATUS, and ∗LAPSE in the *-(a)licious*/*-(a)thon* grammar.

In the next sections, I consider each piece of support for the LWC Hypothesis.

3.1 PCA-conditioning constraints are active elsewhere in the same language

The constraints ∗HIATUS, ∗CLASH, and ∗LAPSE show effects throughout English.

Many authors (Stene and Tillotson 1954; Plag 1999; Britain and Fox 2009) have described a conspiracy of processes that avoid hiatus in English, noting that hiatus is especially marked when the first vowel is lax. These lax-vowel–vowel sequences are avoided at all costs, and following Plag (1999), I use the constraint ∗ə.V to capture the restriction. The effects of ∗HIATUS and ∗ə.V can be observed:

- in the lack of lax-vowel–vowel sequences in mono-morphemic words (Stene and Tillotson 1954)
- in reduction of *the*, which is blocked before vowels (Conway 1878)
- in derivational suffixes such as *-ese*, *-er*, *-y*, *-ize*, and *-ify* (Raffelsiefen 1999)
- in the allomorphic alternation between *a* and *an*
- in optional intervocalic glottal stop epenthesis (Davidson and Erker 2014)
- in obligatory glottal stop epenthesis in [ðə]+V sequences (Keating et al. 1994)

The rhythmic constraints ∗CLASH and ∗LAPSE also show effects across English. Rhythmic constraints condition a large number of cases of grammatical variation:

- derivation with the suffixes *-ese*, *-al*, *-eer*, *-ee*, *-ette*, *-ize*, and *-ify* (Raffelsiefen 1999)
- the dative alternation, *give John the book* vs. *give the book to John* (Anttila, Adams, and Speriosu 2010)
- the genitive alternation, *the car's wheel* vs. the *wheel of the car* (Shih et al. 2015)
- optional *to* (Wasow, Greene, and Levy 2012)
- optional *that* (Lee and Gibbons 2007)
- word order in conjoined NPs (McDonald et al. 1993)
- the Rhythm Rule, which shifts stress leftward to avoid a clash (Liberman and Prince 1977)

Under the LWC Hypothesis, similarities between *-(a)licious*, *-(a)thon*, and these alternations follow from the fact that they are driven by the same constraints. Under subcategorization, such similarities are coincidence. If different affixes are subject to the same conditions, it's because they happen to have similar subcategorization frames.

3.2 There's no historical explanation for the affix's distribution

Under a subcategorization account, there's one possible explanation for why so many suffixes have the same subcategorization frame: cross-suffix similarity follows from historical change. Many cases of PCA are the result of shared sound change, such as the historical resemblance in English between *a*/*an*, *my*/*mine*, and *thy*/*thine* (Berg 2011).

While a historical account is available for some cases, no such account is available for suffixes like *-(a)licious* and *-(a)thon*, which are relatively novel and uncommon. Moreover, suffixes that arose during different time periods, such as *-(e)teria* and *-(a)licious*, obey the same constraints.

3.3 There's insufficient data to learn the affix's distribution

Speakers who learn the distribution of *-(a)licious* must do so with very sparse data. In the 1.9-billion-word corpus discussed in §2, most words with *-(a)licious* occur only once, and the most common *-(a)licious* words have the same phonological shapes.

Despite this, speakers agree on the distribution of *-(a)licious*. If speakers don't learn the distribution of *-(a)licious* through observation, how do they learn it? The answer under the LWC Hypothesis is that speakers simply extend their existing phonology to the new suffixes. All a speaker needs to learn is that there are two forms, *-licious* and *-alicious*, and the phonological grammar handles the rest.

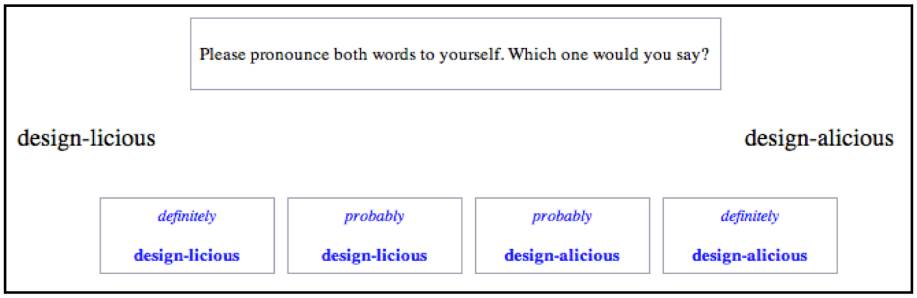
4 Experiment part 1: *CLASH and *HIATUS

In this section, I present the results of a judgment experiment on *-(a)licious* and *-(a)thon*. The experiment is presented in two parts. In part 1, I discuss the items testing whether there are independent effects of final segment and final stress. In part 2, I discuss the items that test the interaction of the suffixes with the Rhythm Rule. Although presented separately, the items are from the same experiment, with the same methods, participants, and materials.

4.1 Methods

Subjects. Subjects were recruited through word-of-mouth and social media, and were not reimbursed in any way. Data were included for the 109 subjects who indicated that they were native English speakers and from the U.S.

Materials. The experiment was conducted online using Ibex.[2] Subjects were presented with *-licious* and *-alicious* variants of a noun, and asked to choose the form they would say, along with indicating their confidence as *definitely* or *probably*. They did the same for other nouns with *-thon* and *-athon*. Choices were presented in English orthography, with a single hyphen between the stem and the suffix. The presentation of the schwaful variant on the right or left side of the screen was random. A screen capture of the experiment in progress is below.



Please pronounce both words to yourself. Which one would you say?

Figure 2: A screen capture of the experiment in progress

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[2] http://spellout.net/ibexfarm/

The experiment tested 50 different stem nouns, varying in stress pattern and final segment. Nouns belonged to one of five different categories, presented below. The numbers in the stress context column represent the stress pattern of the noun: 1 is a primary-stressed syllable; 2 is secondary-stressed syllable; and 0 is an unstressed syllable. None of the experimental stems occur in the corpus. A list of items is included in the appendix.

Stem-type	Stress	Final segment
police-type	01	consonant
thirteen-type	21	consonant
cactus-type	10	consonant
hero-type	10	vowel
underwear-type	102	consonant

Table 13: Experimental conditions

The first three contexts were included to test the effects of final stress and Rhythm Rule (RR), discussed in §5. The *thirteen* and *police* stems contrast RR-eligible (stress: 21) and RR-ineligible stems (stress: 01). The list of police-type nouns and the list of thirteen-type nouns were balanced for frequency and final consonant. Cactus-type stems were included to test the basic stress-conditioning of *-(a)licious* and *-(a)thon*. Hero-type stems match cactus-type words with respect to stress, differing only in final segment.

The experiment also contained secondary-stress-final nouns like *underwear*, to test the effect of final secondary stress, and the difference between weak (secondary-primary) and strong (primary-primary) stress clashes. These words aren't discussed much here, since they are subject to confounds: many speakers show variation between 102 and 201 patterns (límousìne vs. lìmousíne), *-athon* is able to shift stress in underwear-type words (§2.3), and *-(a)licious* may be subject to a size constraint, only occurring with stems shorter than three syllables (§2.5).

The experiment also contained 30 fillers. Like the test items, all fillers compared schwaful and schwaless variants of words derived with *-(a)thon* and *-(a)licious*. The fillers were included to distract from the prosodic conditioning by providing diversity in stress contexts, and more V-final words. They contained a mix of different final consonants and stress contexts, and all were trisyllabic. Ten fillers were presented from each category below. The results for these words were not analyzed in detail, but are included in the appendix.

Stem-type	Stress	Final segment
japanese-type	201	consonant
acoustic-type	010	consonant
alaska-type	010	vowel

Table 14: Phonological contexts of fillers

Every subject saw each stem once (including fillers), paired with either *-(a)thon* or *-(a)licious*. This makes 80 judgments (80 stems), presented in random order. For each subject, half of the judgments were for *-(a)thon*, and half were for *-(a)licious*, and stem-suffix pairings were counterbalanced across subjects.

4.2 Results

In this section, I present the results for all stems, except thirteen-type words, which are discussed in the section on the Rhythm Rule (§5).

Response times. Given that the experiment was conducted over the internet, response time cutoffs were used to ensure that subjects weren't clicking without reading. The mean response time was 2172 ms, which seems reasonable given that subjects were asked to pronounce both forms of the word. Responses were excluded from analysis if they were less than two standard deviations below the log-transformed mean response time: only responses above 294 ms were considered.

Results for -(a)licious. The table below reports the mean proportion of schwaful responses for *-(a)licious* stems.

Stem type	Context	Proportion *-alicious*
police-type	01 C-final	0.93
cactus-type	10 C-final	0.45
hero-type (all)	10 V-final	0.07

Table 15: Table of means for *-(a)licious*

The results are also plotted in the graph below, which shows the same order as the corpus data. C-final iambs (*police*) are most likely to take *-alicious*, while V-final trochees (*hero*) are least. C-final trochees (*cactus*) are between.

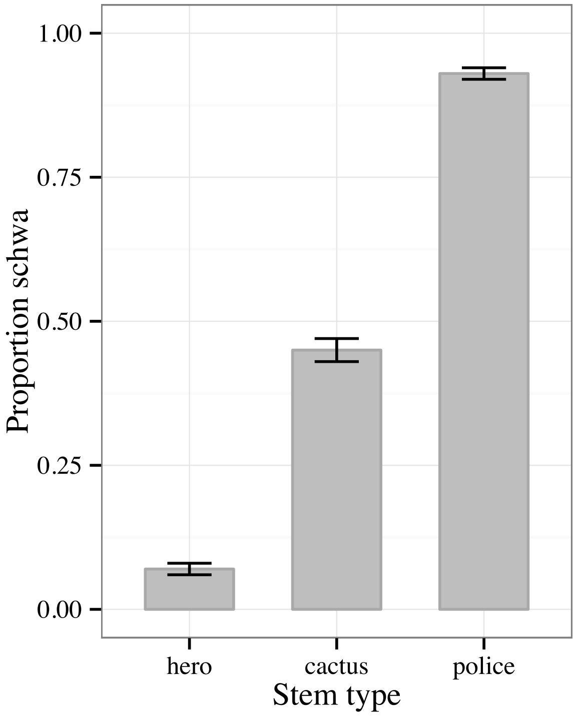

Figure 3: Proportion of *-alicious* responses in judgment experiment

The hero-type stems can be further divided based on their final vowel. Six of the stems end in full vowels (*chili*, *cookie*, *hero*, *jackie*, *menu*, *zero*), and four end in schwa (*china*, *cuba*, *drama*, *russia*). The full vowel stems are more likely to take *-alicious* than the schwa stems (0.09 vs. 0.04). This mirrors the stronger dispreference for lax-vowel–vowel sequences found in the rest of English (§3).

Chi-square tests were performed on the contrasts of theoretical interest: final vs. non-final stress, V-final vs. C-final, and so on. The results are in the table below.

Contrast	Groups compared	Chi-square (d.f.)	p-value
final • non-final stress	police • cactus	222.37 (1)	p<0.001
final V • final C	hero • cactus	122.15 (1)	p<0.001
final schwa • final full vowel	hero • hero	3.94 (1)	p<0.05

Table 16: Chi-square tests for *-(a)licious*

The tests above show that both final segment and final stress condition *-(a)licious*. The schwaful form is more likely with final-stress stems (*police*) than non-final-stress stems (*cactus*). In addition, *-alicious* is less likely with V-final stems (*hero*) than C-final stems (*cactus*). Among V-final stems, *-alicious* is more likely after a full vowel than a schwa.

Results for -(a)thon. The mean proportions of schwa responses for *-(a)thon* are presented in the table below. Overall, there were more schwaful responses for *-(a)thon* than *-(a)licious*, mirroring the differences found in the corpus data.

Stem type	Context	Proportion *-athon*
police-type	01 C-final	0.99
cactus-type	10 C-final	0.79
hero-type (all)	10 V-final	0.32

Table 17: Table of means for *-(a)thon*

The results for *-(a)thon* follow the same pattern as *-(a)licious*. V-final trochees (like *hero*) prefer *-thon*, while C-final iambs (like *police*) prefer *-athon*. Again, C-final trochees (*cactus*) are between.

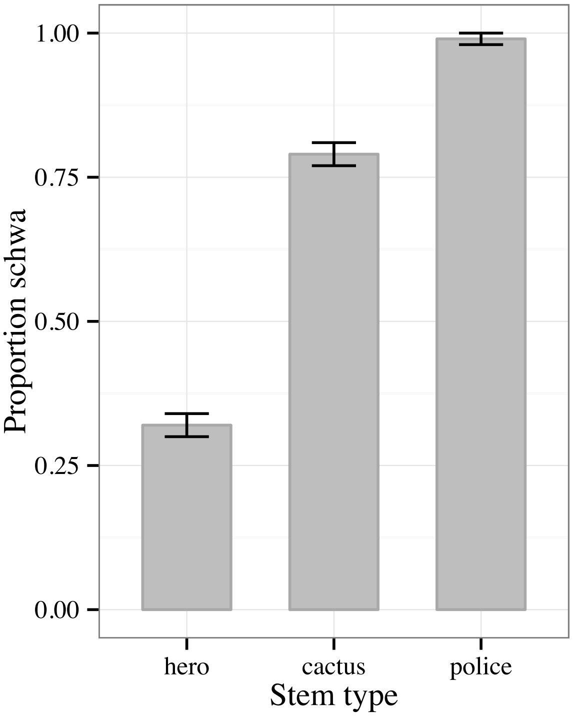

Figure 4: Proportion of *-athon* responses in judgment experiment

The difference between full V-final and schwa-final stems is even more noticeable with *-(a)thon*. Full vowel-final stems are more likely to take *-athon* than schwa-final stems (0.48 vs. 0.10).

Chi-square tests were performed for each comparison of interest. These tests show a significant effect of stress and final segment, and a significant effect of final vowel type.

Contrast	Groups compared	Chi-square (d.f.)	p-value
final • non-final stress	police • cactus	102.74 (1)	p<0.001
final V • final C	hero • cactus	165.34 (1)	p<0.001
final schwa • final full vowel	hero • hero	88.8 (1)	p<0.001

Table 18: Chi-square tests for *-(a)thon*

4.3 Optionality

Recall that in addition to collecting data on schwa vs. no schwa, the experiment asked subjects to rate their confidence in their answers as *definitely* or *probably*. In the graph below, each point is a word in the experiment. The graph plots how categorically a word prefers schwa against the proportion of *definitely* responses for that word. As the distance from 50% increases, subjects become more confident in their individual responses. In other words, when the population is split on whether a stem should take *-alicious* or *-licious*, each individual is less certain of their response.

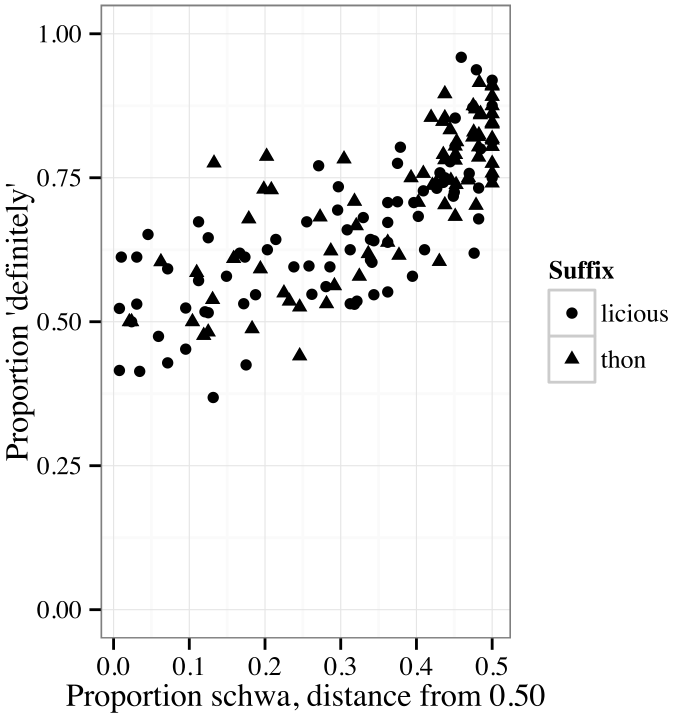

Figure 5: Proportion of schwa by confidence, grouped by stem

The graph above is important because the presence of intraspeaker variation isn't apparent from the corpus data alone. With the exception of *babe-alicious*, nearly no stems occur with both schwaful and schwaless suffixes in the corpus. The experimental results, on the other hand, clearly show that -*(a)licious* and -*(a)thon* are subject to intraspeaker variation, and are not simply a result of averaging across speakers.

4.4 Comparison of -(a)thon and -(a)licious

Like the corpus search, the experiment finds that both suffixes obey similar conditioning, but schwa is more likely in -*(a)thon* than -*(a)licious*.

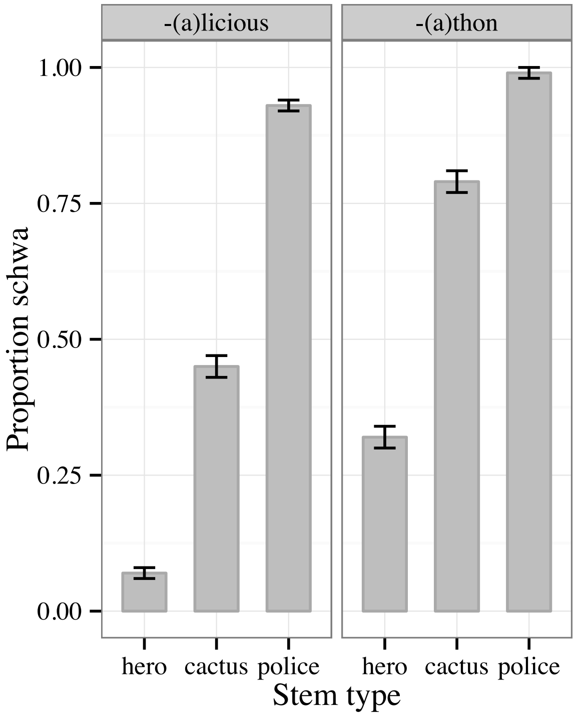

Figure 6: Proportion of -*alicious* (L) and -*athon* (R) responses in judgment experiment

This difference between -*(a)thon* and -*(a)licious* is consistent across both items and subjects. Schwa is more likely in -*(a)thon* than -*(a)licious* for 78 out of 80 stems.[3] The graph below shows the proportion schwa for each suffix. Each point is a stem, and points above the dotted diagonal line have a higher proportion of schwa in -*(a)thon* than -*(a)licious*.

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[3] The exceptions are fillers *korea* and *gorilla*, possibly due to their liquids.

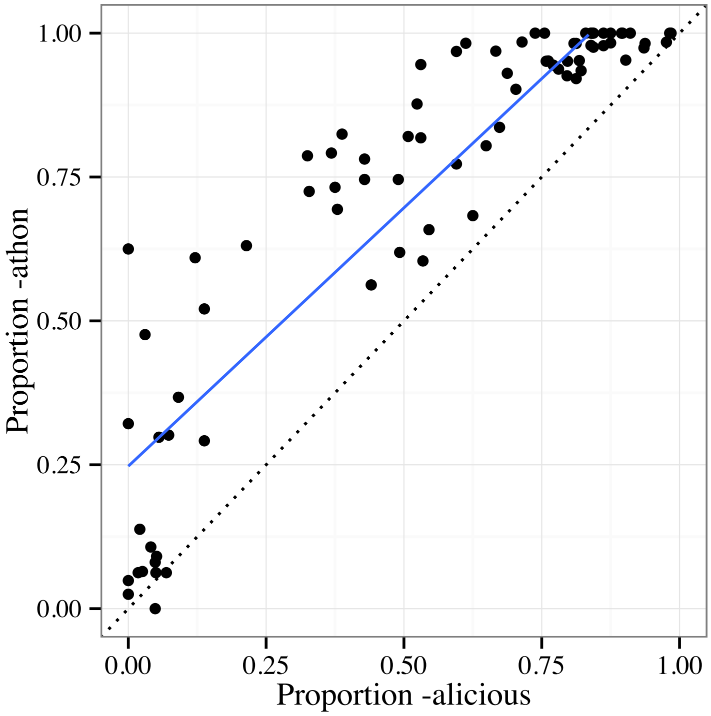

Figure 7: Proportion of schwa for each suffix, grouped by stem. Solid line is line of best fit (slope=0.90, adjusted r^2= 0.82). Dotted line shows values where proportions of *-alicious* and *-athon* are equal

This graph also shows that for each stem, the proportion of schwa in *-(a)licious* is strongly correlated with the proportion of schwa in *-(a)thon*, r(78)=0.91, p<0.001. If a stem is likely to take *-alicious*, it's also likely to take *-athon*. A similar graph for the 109 subjects is below. Only 12/109 participants use schwa more often in *-(a)licious* than *-(a)thon*. These are the points below the dotted line.

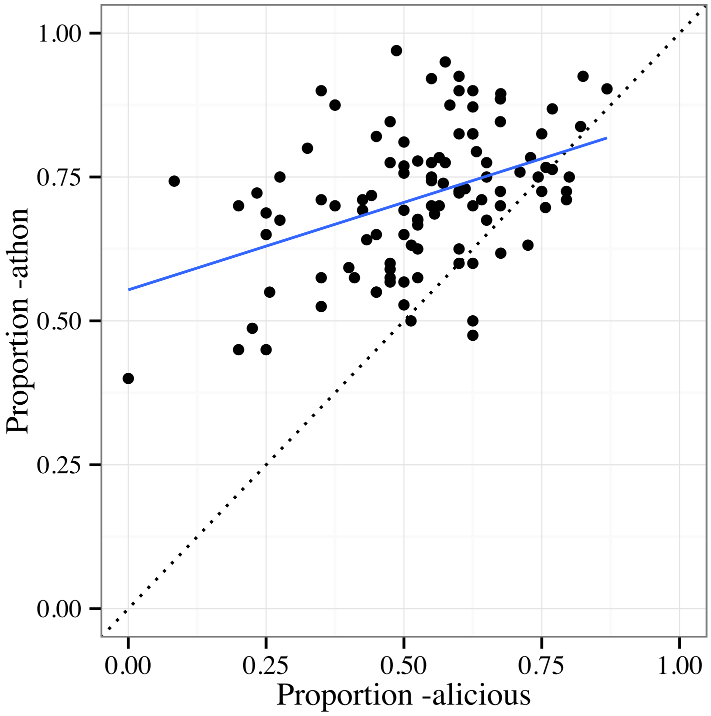

Figure 8: Proportion of schwa for each suffix, grouped by subject. Solid line is line of best fit (slope=0.30, adjusted r^2= 0.16). Dotted line shows values where proportions of *-alicious* and *-athon* are equal

For each subject, there is a weak but significant correlation between use of *-alicious* and use of *-athon*, r(109)=0.41, p<0.001. Speakers who use schwa more often with one suffix are more likely to use schwa with the other.

4.5 Summary and comparison with corpus

In summary, the experiment finds independent effects of final segment and final stress for both suffixes, along with a difference between the overall rates of schwa in *-(a)licious* and *-(a)thon*.

The experiment mirrors the findings of the corpus study, despite the lack of overlap between the stems in the corpus and the stems in the experiment. The replication of the corpus findings is most important for cactus-type stems, which are under attested in the corpus. Cactus-type stems only occur in 31 licious-words, all of which only occur once in GloWbE (out of 1.9 billion words). The convergence of these two types of data supports the claim that speakers really do know the distribution of *-(a)licious* and *-(a)thon*, even in the face of sparse learning data.

The graph below summarizes the corpus and experiment.

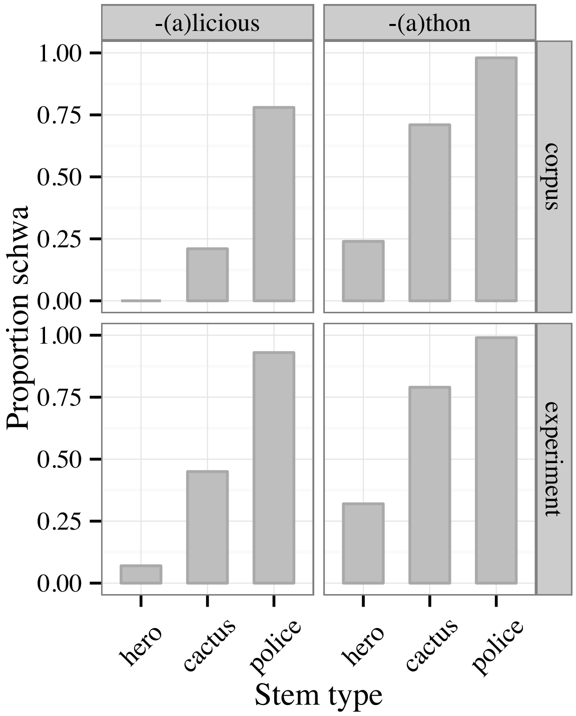

Figure 9: Comparison of experimental and corpus results for *-(a)licious* and *-(a)thon*

For both suffixes, schwa is more likely in the experiment than the corpus, but otherwise, the results are similar.

5 Experiment part 2: the Rhythm Rule

In this section, I present the rest of the experimental results, focusing on the interaction between *-(a)licious*, *-(a)thon*, and the Rhythm Rule, a phonological alternation that resolves stress clash. Both suffix selection and the Rhythm Rule conspire to avoid stress clash, providing an additional argument for the clash-driven nature of *-(a)licious* allomorphy.

These results also support a model in which UR selection and the phonological grammar occur in parallel. They provide an example of the chicken-egg effect (McCarthy 2002), a case where two processes must both apply first, creating an ordering paradox.

(33) The chicken-egg effect, a consequence of parallelism (McCarthy 2002)
The application of process A depends on knowing the output of process B, and the application of process B depends on knowing the output of process A.

The Rhythm Rule must paradoxically apply both before and after the form of the suffix is chosen.

(34) Chicken-egg effect in *-(a)licious* and the Rhythm Rule

a. The Rhythm Rule is triggered by the suffix chosen
b. The suffix chosen depends on whether the Rhythm Rule can apply

To capture these facts, UR selection must have lookahead to the output of phonological rules like the Rhythm Rule. This is possible in a model in which UR selection occurs at the same time as phonology, such as the model outlined in §6, which shares this property with most OT models of PCA.

5.1 Clash and the Rhythm Rule

The Rhythm Rule (RR) is a phonological repair that resolves stress clash by retracting stress to an earlier syllable. It has been discussed extensively in earlier work, such as Liberman and Prince (1977), Prince (1983), Hayes (1984) and many others (see Tilsen 2012 for an overview). I remain noncommittal with respect to the formulation of RR, whether it's prominence transfer, accent deletion, node relabeling, or something else. Instead, I focus on the requirements for its application, which are generally agreed upon in the literature.

The Rhythm Rule resolves stress clash by reducing the prominence of the first syllable in a stress clash (the second syllable in *Diane*). This causes an increase in the relative prominence of a stressed syllable earlier in the word. [4]

(35) The Rhythm Rule

a. D$\overset{2}{\imath}\overset{1}{a}$ne
b. D$\overset{2}{\imath}\overset{3}{a}$ne Ch$\overset{1}{a}$mbers

Stress retraction is only possible if there is a stressed syllable earlier in the word, before the stress clash: RR cannot apply in a phrase like *aghast student*, since the first syllable of *aghast* is unstressed.

5.2 Predictions of a parallel model for *-(a)licious*

Recall that *-(a)licious* carries main stress in the word it derives. For example, main stress falls on *licious* in *t$\overset{2}{u}$rkey-l$\overset{1}{\imath}$cious*. As a result, *-licious* is able to trigger RR when it occurs with a stem such as *th$\overset{2}{\imath}$rt$\overset{1}{e}$en*, as shown below.

(36) th$\overset{3}{\imath}$rt$\overset{2}{e}$en-l$\overset{1}{\imath}$cious → th$\overset{2}{\imath}$rt$\overset{3}{e}$en-l$\overset{1}{\imath}$cious

As mentioned above, RR won't apply in a word like *police-licious*, since stress is unable to shift to the initial schwaful syllable. The fact that *-licious* is able to trigger RR in some stems (*thirteen*) but not others (*police*) provides a way to distinguish parallel and derivational models.

Parallel model. In a parallel model like the one in §6, all combinations of suffixes and RR application are considered together in the candidate set. Nearly every OT account of PCA has

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[4] Experimental studies (Horne 1993; Tilsen 2012), however, show that absolute prominence of the first syllable doesn't change.

this property, e.g. Mester (1994), Kager (1996), and Mascaró (1996), and this property often goes hand-in-hand with the Language-wide Constraint Hypothesis.

For a word like *thirteen*, there are four relevant candidates. In the candidates below, the first two have undergone RR, and the second two have not. Only one candidate violates ∗Clash (containing an overset 2 next to an overset 1). For *thirteen+(a)licious*, then, there are three ways to avoid a stress clash.

(37) Candidate set for *thirteen-(a)licious*

a.	th$\overset{2}{\text{i}}$rt$\overset{3}{\text{ee}}$n-l$\overset{1}{\text{i}}$cious	shifted stress via RR, satisfies ∗Clash
b.	th$\overset{2}{\text{i}}$rt$\overset{3}{\text{ee}}$n-$\underline{\text{a}}$l$\overset{1}{\text{i}}$cious	shifted stress via RR, satisfies ∗Clash
c.	th$\overset{3}{\text{i}}$rt$\overset{2}{\text{ee}}$n-l$\overset{1}{\text{i}}$cious	violates ∗Clash
d.	th$\overset{3}{\text{i}}$rt$\overset{2}{\text{ee}}$n-$\underline{\text{a}}$l$\overset{1}{\text{i}}$cious	satisfies ∗Clash

For a word like *police*, in which RR cannot apply, only one clashless candidate is viable. The candidates with shifted stress are ruled out by the restrictions on the application of RR. The only way for a speaker to avoid a stress clash with *police* is the schwaful allomorph *-alicious*.

(38) Candidate set for *police-(a)licious*

a.	pol$\overset{2}{\text{i}}$ce-l$\overset{1}{\text{i}}$cious	violates ∗Clash
b.	pol$\overset{2}{\text{i}}$ce-$\underline{\text{a}}$l$\overset{1}{\text{i}}$cious	satisifies ∗Clash
c.	*p$\overset{2}{\text{o}}$lice-l$\overset{1}{\text{i}}$cious	shifted stress ruled out by RR restrictions
d.	*p$\overset{2}{\text{o}}$lice-$\underline{\text{a}}$l$\overset{1}{\text{i}}$cious	shifted stress ruled out by RR restrictions

In the parallel model, there are three ways to avoid stress clash for *thirteen-(a)licious*, but only one way for *police-(a)licious*. Assuming a speaker takes advantage of these extra options, a thirteen-type stem should take *-licious* more often than a police-type stem. A police-type stem never has a reason to take *-licious*; the only way to avoid stress clash is using the schwaful suffix.

Derivational model. In many derivational models of morphophonology, UR selection occurs either before or after phonological alternations like RR, but not at the same time. This holds for nearly every account in Distributed Morphology (e.g. Embick 2010), and some accounts in derivational OT, such as Wolf (2008)'s OT-CC account, and any account in Harmonic Serialism that assumes UR selection is an operation (e.g. Wolf 2014).

If UR selection is evaluated as a separate step from phonological operations, there should be no difference between *police* and *thirteen*. If phonology happens before suffix selection, then RR doesn't apply, since there's no suffix to trigger RR. If suffix selection happens first, a stem's ability to undergo RR will be irrelevant. Either way, all words with final stress will prefer *-licious* and *-alicious* to the same degree, regardless of whether they undergo RR.

This prediction only holds so long as there is no other way to distinguish police- and thirteen-type stems. Imagine, for instance, a subcategorization frame for *-alicious* that prefers stress-final stems with a preceding secondary stress (such as *thirteen*). This subcategorization frame could capture a difference between *police* and *thirteen*, but there are reasons to doubt it. This subcategorization frame perfectly mirrors the conditions on RR, duplicating a phonological rule in the lexicon. Additionally, it refers to non-local phonological context, for instance, a secondary stress somewhere earlier in the word. Subcategorization frames are generally taken to be local, for instance, in Paster (2009). Finally, if the corpus results are any indication, there's practically no evidence for such a subcategorization frame for language learners. In the corpus, less than 1% of the stems that occur with *-(a)licious* have final stress with a preceding secondary stress.

A second prediction for the parallel account. While a parallel account predicts a difference between *police* and *thirteen* for *-(a)licious*, this difference should disappear for *-(a)thon*. Unlike *-(a)licious*, *-(a)thon* takes secondary stress in the words it derives, as in *thirt*$\overset{1}{e}$*en-th*$\overset{2}{o}$*n*. This property prevents RR application, which never shifts stress from a syllable with primary stress. This is shown by the pair *àntique ármchair*, where stress retracts, and *antíque dèaler*, where it cannot.

In a parallel model, the choice between a schwaful or schwaless suffix being chosen is directly linked to RR eligibility. For a suffix like *-licious*, which triggers RR, there should be a difference between RR-eligible stems like *thirteen* and RR-ineligible stems like *police*. For a suffix like *-thon*, which never triggers RR, there should be no difference.

A derivational model, on the other hand, predicts no relationship between RR-eligibility and suffix selection. If such a relationship exists, it's a coincidence, and must be accounted for with subcategorization frames that differentiate *thirteen* and *police*, in addition to *-(a)licious* and *-(a)thon*.

5.3 Experimental results

The table below presents the experimental results with thirteen-type stems included. These results are consistent with the parallel model. RR-eligible stems (*thirteen*) are more likely to appear with *-licious* than RR-ineligible stems (*police*) (chi square= 38.60, df= 1, p<0.001). The difference between thirteen-type and police-type stems disappears for *-(a)thon*. With *-(a)thon*, there is no significant difference between RR-eligible and RR-ineligible words (chi square = 0.64, df = 1, p = 0.42). As mentioned in §4, police-type and thirteen-type stems were balanced with respect to lexical frequency and final segment.

Stem type	Context	Proportion *-alicious*	Proportion *-athon*
police-type	01 C-final	0.93	0.99
thirteen-type	21 C-final	0.80	0.98
cactus-type	10 C-final	0.45	0.79
hero-type	10 V-final	0.07	0.29

Table 19: Table of means for *-(a)licious*

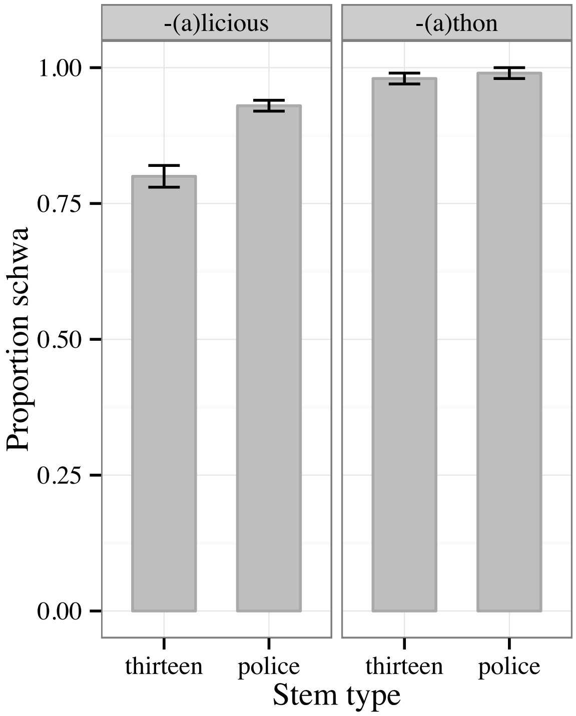

Figure 10: Proportion of schwa responses for thirteen-type and police-type stems from experiment

While significant overall, RR-eligibility doesn't have an effect for every subject, but of the subjects who do show a difference, the majority show one in the predicted direction. For *-(a)licious*, the predicted difference between police-type and thirteen-type stems holds for 44% of subjects, while 47% show no difference, and the remainder (9%) show a difference in the opposite direction. In the table below, I divide subjects by geographic region, based on their self-reported location, and the regional divisions in the R dataset of state divisions (R Core Team 2013).[5] Regional information is included because Southern English tends to shift stress to the initial syllable of nouns, e.g. *úmbrella*, *chínese*, especially when there's a preceding secondary stress, although this can't explain the intermediate status of *thirteen* across regions.

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[5] For more information, see 'state.name' and 'state.region' in R, and the helpfile 'state'.

	Midwest	Northeast	Northwest	South	West	Total
More schwa with police-type	13	14	4	13	4	48
No difference	9	19	5	10	8	51
More schwa with thirteen-type	1	7	0	0	2	10

Table 20: Counts of subjects who show differences between police-type and thirteen-type stems for *-(a)licious*

While about half of the subjects show an effect of RR in *-(a)licious*, only 9 out of 109 subjects show a difference between police-type and thirteen-type stems for *-(a)thon*. The nine subjects who show a difference are split 4–5 with respect to which stem type takes schwa more often.

There are a few possible explanations for the fact that only half of subjects show sensitivity to RR. First, RR is a variable process, and the exact likelihood of its application isn't known. Grabe and Warren (1995) find that speakers retract stress about 85% of the time in clash contexts in a spoken production experiment. Second, it's been recently suggested that RR requires production planning. In an experiment, Tilsen (2012) finds that RR effects can be observed in prepared speech but not in unprepared speech. If speakers don't read the items aloud, they may fail to apply the rule. Finally, RR fails to apply with certain lexical items, and exceptions differ across speakers (Bolinger 1981). For example, the word *obese* does not undergo RR, even in clashing contexts.

Overall, speakers treat RR-eligible and RR-ineligible stems differently, and this difference disappears for *-(a)thon*. To further support the differences between *-(a)thon* and *-(a)licious*, I present the results of a mixed effects regression model in the next section, which finds a significant interaction between RR-eligibility and suffix.

The rest of this section addresses some more potential confounds and possible objections to the results above. The answer to most objections can be found in the interaction between RR-eligibility and suffix. Any property of the stems that could be used to explain the difference between thirteen-type and police-type stems cannot account for the lack of difference in *-(a)thon*. If some property makes thirteen-type stems favor *-licious*, that same property should make them favor *-thon*.

A ceiling effect. One potential complication is that the proportions for *-(a)thon* are close to 1.0. The lack of difference for *-(a)thon* could be due to a ceiling effect.

The difference between *-(a)licious* and *-(a)thon* holds when we move away from the ceiling. This is possible by binning the responses differently. Recall that subjects indicated their confidence as *definitely* or *probably*, in addition to choosing a suffix. If we look at the proportion of *definitely -athon* responses, the rate of schwa drops to 0.72 for police-type stems and 0.70 for thirteen-type stems, but the size of the difference remains the same: 0.02. This difference is not significant in a chi-square test (chi-square = 0.41, d.f. = 1, p = 0.52). We still find a difference for *-(a)licious*. Subjects chose *definitely -alicious* 53% of the time for police-type stems, and 45% of the time for thirteen-type stems, a significant difference (chi-square = 14.53, d.f. = 1, p < 0.001).

Interspeaker variation. The results for thirteen-type words are complicated by interspeaker variation with respect to secondary stress. As pointed out in Cooper and Eady (1986), many words that undergo RR (such as *thirteen*) are pronounced with initial stress even in non-RR contexts, at least for some speakers. The experimental findings could be dismissed as a result of this variation: some speakers say *thirteen* with initial stress, some with final, and the mixture of these speakers puts it between *cactus* and *police*.

There are two responses to this objection. First, if thirteen-type words vary between pronunciations, there's no reason why they'd vary with *-(a)licious* but not with *-(a)thon*. Second, the difference between police-type and thirteen-type responses is not dependent on one or two items subject to variation. For *-(a)licious*, every police-type stem takes schwa at higher rate than every thirteen-type stem, and likewise for thirteen-type and cactus-type stems. There is no overlap between stem-types with respect to the proportion of schwa. For *-(a)thon*, there is a great deal of overlap: police-type and thirteen-type stems take schwa at the same rates. A full list of proportions by stem can be found in the appendix.

Spelling. A final confound is spelling. The items were presented with a hyphen between the stem and suffix, but it's possible that subjects interpreted a schwa where none was intended, for example, the *e* in *police-licious*. There are three reasons that spelling is nothing to worry about here. First, conditions don't differ too much with respect to their number of final *e*'s: 8/10 thirteen-type stems end in *e*, while 6/10 police-type stems do. Second, all thirteen-type stems have lower rates of *-alicious* than all police-type stems. Even if we disregard *e*-final stems, the effect of RR remains. Finally, spelling can't explain why the effect of RR is present in *-(a)licious*, but disappears with *-(a)thon*.

5.4 Regression model

To see if there was an interaction between RR-eligibility and suffix, results were analyzed using a mixed-effects logistic regression model. The analysis was performed using the lme4 package (Bates et al. 2013) in R (R Core Team 2013). The independent variable was schwa vs. no schwa.

The model included predictors for stress pattern (Non-Final), RR-eligibility (rr), suffix (Suffix), and the interaction of RR-eligibility and suffix. The coding of these is discussed below. The model did not include a predictor for final segment, and hero-type stems were excluded. A model with hero-type stems failed to converge with a full set of random slopes. This may be because all of the V-final items in the experiment have non-final stress. As a result, many combinations of final segment, RR-eligibility, and stress are missing from the data.

Stress pattern. The different stress contexts were coded as a 3-level factor, ordered in the direction predicted by the parallel model. This three-way contrast was divided into two predictors using Helmert coding: Non-Final for non-final stress and rr for Rhythm Rule.

Level	Stress pattern	NON-FINAL	RR	stem types
Level 1	10	+2	0	cactus
Level 2	21	−1	+1	thirteen
Level 3	01	−1	−1	police

Table 21: Contrasts for NON-FINAL and RR

NON-FINAL compares Level 1 with higher levels (10 vs. 21 and 01), while RR compares Level 2 with higher levels (21 vs. 01). RR ignores cactus-type stems, since they have a value of 0.

Suffix. The contrasts for SUFFIX are below.

Context	SUFFIX	Examples
-(a)licious	+1	cactus-(a)licious, police-(a)licious, etc.
-(a)thon	−1	cactus-(a)thon, police-(a)thon, etc.

Table 22: Contrasts for SUFFIX

Interaction RR x SUFFIX. The model included an interaction term for RR and SUFFIX. The values for each condition are show below. Note that RR x SUFFIX cancels out RR for *-(a)thon*, but heightens the difference between *police* and *thirteen* for *-(a)licious*. Like RR , RR x SUFFIX ignores cactus-type stems.

	RR x SUFFIX	RR	SUFFIX
thirteen-licious	+1	+1	+1
cactus-licious	0	0	+1
police-licious	−1	−1	+1
thirteen-thon	−1	+1	−1
cactus-thon	0	0	−1
police-thon	+1	−1	−1

Table 23: Interaction term RR x SUFFIX

Model and results. The model included predictors for stress pattern (NON-FINAL), Rhythm Rule eligibility (RR), suffix (SUFFIX), and the interaction term RR x SUFFIX. The model also included random intercepts for Subject and Item, in addition to random slopes by Subject for all predictors, including the interaction term. [6]

The results of the model are presented below. Effects with a Z value greater than 2 or less than –2 are significant. In the table below, a positive estimate (β) indicates that as the predictor increases, the likelihood of the schwaful variant (*-alicious* or *-athon*) increases. A negative one indicates that the likelihood of the schwaful variant decreases as the factor increases. In other words, positive means more schwa, and negative means less.

	β	SE	z value	p value
(Intercept)	2.01	0.18	16.08	
Non-Final	-1.05	0.08	−12.78	<0.001
RR	-0.22	0.17	-1.24	0.21
Suffix	-1.14	0.10	-11.70	<0.001
RR x Suffix	-0.60	0.15	-3.93	<0.001

Table 24: Logistic regression results

All of the predictors included in the model were significant, except for rr.

Non-final: The negative value shows that non-final-stress stems are more likely to occur with *-licious* and *-thon* than *-alicious* and *-athon*. In other words, stress-final stems are more likely to occur with a schwaful suffix.

Suffix: The negative value of the factor Suffix shows that words with *-(a)licious* are less likely to occur with schwa than words with *-(a)thon*.

rr x Suffix: The significant interaction between rr and Suffix shows that RR-eligibility has a greater effect in words derived with *-(a)licious* than in words derived with *-(a)thon*. The negative value means that RR-eligible stems with *-(a)licious* are less likely to take schwa than we'd expect given the effects of rr or Suffix alone.

The result for rr x Suffix is the one most of interest here: the effect of RR-eligibility is dependent on suffix. It's this interaction that provides support for a parallel model. In the parallel model, the choice of suffix is closely tied to whether or not RR can apply. RR will only have an effect with suffixes that can trigger it. For a suffix that can't trigger RR (like *-(a)thon*), there should be no difference between RR-eligible stems (*thirteen*) and RR-ineligible ones (*police*).

6 MaxEnt-HG model of experimental results

The goal of this section is a probabilistic model that can capture the phonological conditioning of *-(a)thon* and *-(a)licious*. A successful model captures the descriptive generalizations below, and roughly matches the probabilities from the experiment.

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[6] The regression equation in R: Response ~ Non-final + rr*Suffix + (1 + Non-final + rr*Suffix | Subject) + (1|Item); family=binomial; link=logit

- Overall, schwa is more likely in *-(a)thon* than *-(a)licious*.
- *-(a)thon* and *-(a)licious* are conditioned by final segment and final stress.
- Full vowel-final stems (*hero*) take schwaful allomorphs more than schwa-final stems (*soda*).
- *-(a)licious* interacts with the Rhythm Rule.

In the model here, all of the generalizations above follow from the interaction of weighted constraints in a MaxEnt grammar (Goldwater and Johnson 2003). Phonological conditioning comes from markedness constraints, while the difference in baseline rates for *-athon* and *-alicious* comes from UR constraints. The model is able capture the probabilities for both *-(a)licious* and *-(a)thon* with a single weighting of constraints, as required by the LWC Hypothesis.

At the end of the section, I use English phonotactics to evaluate the model, showing that the weights for the markedness constraints conditioning *-(a)licious* and *-(a)thon* are consistent with the distribution of words in English. This suggests that learners have enough data from phonotactics to acquire the markedness constraint weights for the suffixes. In this way, *-(a)licious* and *-(a)thon* data provide a window into English phonology: a model fit only with the experimental data is consistent with the entire English lexicon.

6.1 MaxEnt-HG

Previous work on PCA in constraint-based grammars is couched in Optimality Theory, in which constraints are ranked and a single candidate is optimal (Prince and Smolensky 1993/2004). An alternative model is one in which constraints are weighted, such as Maximum Entropy Harmonic Grammar (MaxEnt: Goldwater and Johnson 2003), which outputs a probability distribution over candidates.

In MaxEnt, each constraint is assigned a numerical weight. The harmony score of each candidate is equal to its sum of weighted violations. The probability of each candidate in its candidate set is proportional to the exponential of its harmony score. In the resulting probability distribution, candidates with a lower harmony score receive less probability. In the modeling here, violations are always negative or zero, and weights are always positive.

6.2 UR Constraints

In the model, UR selection is evaluated at the same time as phonological processes, and the input to phonological evaluation does not contain any phonological material. Instead, the input contains s *meaning* or *intent*. In this way, it resembles a production model. The speaker has some intent, encoded here as morphosyntactic features, and the grammar's goal is to realize it. The idea that the input to phonology contains no phonological material has been pursued extensively in earlier work, such as Russell (1995), Zuraw (2000), Boersma (2001), and Wolf (2008) (among others, see Wolf 2014 for a recent summary).

Given that the phonology governs UR selection, there needs to be some way for the phonology to know the set of possible meaning-UR mappings. These mappings are encoded as UR constraints. The formulation for UR constraints here closely follows Pater et al. (2012) and

Smith (2015). Similar constraints on meaning-UR mappings are proposed in Boersma (2001), called Lexical Constraints.

A UR constraint requires a particular input to be realized by a particular UR.

(39) INPUT → /UR/
Assign one violation for every INPUT that does not correspond to /UR/.

In this model, the INPUT is a set of features, and /UR/ consists of any string of phonological segments, including the empty string. The UR constraints for *-(a)licious* and *-(a)thon* are below.

(40) LICIOUS → /əlɪʃəs/
Assign one violation for every input LICIOUS that does not correspond to /əlɪʃəs/.
(abbreviated UR = /əlɪʃəs/)

(41) LICIOUS → /lɪʃəs/
Assign one violation for every input LICIOUS that does not correspond to /lɪʃəs/.
(abbreviated UR = /lɪʃəs/)

UR constraints are language-specific. The constraints above don't exist in French or Chinese.

6.3 Constraints and violations

To model the *-(a)licious* and *-(a)thon* data, I use the four markedness constraints below, discussed in §3.

(42) ∗CLASH
Assign one violation mark for every sequence of two stressed syllables.

(43) ∗LAPSE
Assign one violation mark for every sequence of two unstressed syllables.

(44) ∗HIATUS
Assign one violation mark for every sequence of two vowels.

(45) ∗ə.V
Assign one violation mark for every sequence of two vowels, where the left vowel is lax.

In addition, I use two constraints for RR. The first militates against RR application, under the assumption that stress is present in URs.

(46) FAITH(STRESS)
Assign one violation mark for every stressed vowel in the input that corresponds to a stressless vowel in the output.

The second is a constraint that enforces two conditions on RR. The first condition prevents retracting stress to a schwaful syllable, e.g. retracting stress to the first syllable in *police*. The second condition prevents retracting a main stress in a phrase, e.g. retracting stress from *antique* in *antique armchair*, or from *thirteen* in *thirteen-licious*. These two conditions are inviolable in English, so they're grouped together in a single constraint for ease of presentation.

(47) RR Rules
Assign one violation for every UR-SR pair that violates at least one condition on RR. The conditions are: (1) if schwa in the input, then stressless in the output. (2) if main stress in the input, then stressed in the output.

Finally, there are four UR constraints, two for *-(a)licious* and two for *-(a)thon*.

(48) UR = /əlɪʃəs/

(49) UR = /lɪʃəs/

(50) UR = /əθɑn/

(51) UR = /θɑn/

The tableau below shows the violations for the four types of stem with *-(a)licious*. I don't consider unfaithful mappings, such as candidates with epenthesis and deletion.

	*Clash	*Lapse	*ə.V	*Hiatus	Faith(Stress)	RR Rules	UR = /lɪʃəs/	UR = /əlɪʃəs/
pol$\overset{2}{\text{ı}}$ce-al$\overset{1}{\text{ı}}$cious							−1	
pol$\overset{2}{\text{ı}}$ce-l$\overset{1}{\text{ı}}$cious	−1							−1
p$\overset{2}{\text{o}}$lice-al$\overset{1}{\text{ı}}$cious (RR)		−1			−1	−1	−1	
p$\overset{2}{\text{o}}$lice-l$\overset{1}{\text{ı}}$cious (RR)					−1	−1		−1
thirt$\overset{2}{\text{e}}$e-al$\overset{1}{\text{ı}}$cious							−1	
chin$\overset{2}{\text{e}}$se-l$\overset{1}{\text{ı}}$cious	−1							−1
th$\overset{2}{\text{ı}}$rteen-al$\overset{1}{\text{ı}}$cious (RR)		−1			−1		−1	
th$\overset{2}{\text{ı}}$rteen-l$\overset{1}{\text{ı}}$cious (RR)					−1			−1
cactus-alicious		−1					−1	
cactus-licious								−1
hero-alicious		−1		−1			−1	
hero-licious								−1
soda-alicious		−1	−1	−1			−1	
soda-licious								−1

Table 25: Constraint violations for *-(a)licious*

Before moving on, let's consider what's these constraints and violations predict. In MaxEnt, the probability assigned to a candidate is proportional to the exponential of its weighted constraint violations. Assuming non-zero weights and given the candidates and violations above, *soda-alicious* will always be less likely than *hero-alicious*. The schwaless forms of both will always have the same harmony score, but *soda-alicious* will always have a lower harmony score than *hero-alicious*. As a result of this lower harmony score, it will take up less of the probability distribution. Likewise, *hero-alicious* will be less probable than *cactus-alicious*, regardless of weights. The violations of *hero-alicious* are a superset of those of *cactus-alicious*, while the *-licious* forms have the same violations.

In summary, we expect *soda-licious* to be more likely than *hero-licious*, and *hero-licious* to be more likely than *cactus-licious*. This is a straightforward consequence of the constraints of English, and holds for any set of non-zero, non-negative weights.

The violations for *-(a)thon* are below. They differ from *-(a)licious* in two ways. First, *-(a)thon* is subject to a different set of UR constraints. Second, since *-(a)thon* takes secondary stress in derived words, RR is blocked. This can be seen in the two violations of RR RULES, highlighted in boxes below. Because of these violations, *police-(a)thon* and *thirteen-(a)thon* have identical violation profiles, and are predicted to always have the same probability distribution across candidates, regardless of constraint weights.

	*Clash	*Lapse	*ə.V	*Hiatus	Faith(Stress)	RR Rules	ur = /θɑn/	ur = /əθɑn/
pol$\overset{1}{\text{i}}$ce-ath$\overset{2}{\text{o}}$n							−1	
pol$\overset{1}{\text{i}}$ce-th$\overset{2}{\text{o}}$n	−1							−1
p$\overset{1}{\text{o}}$lice-ath$\overset{2}{\text{o}}$n (RR)		−1			−1	−1	−1	
p$\overset{1}{\text{o}}$lice-th$\overset{2}{\text{o}}$n (RR)					−1	−1		−1
thirt$\overset{1}{\text{e}}$en-ath$\overset{2}{\text{o}}$n							−1	
thirt$\overset{1}{\text{e}}$en-th$\overset{2}{\text{o}}$n	−1							−1
th$\overset{1}{\text{i}}$rteen-ath$\overset{2}{\text{o}}$n (RR)		−1			−1	$\boxed{-1}$	−1	
th$\overset{1}{\text{i}}$rteenth$\overset{2}{\text{o}}$n (RR)					−1	$\boxed{-1}$		−1
cactus-athon		−1					−1	
cactus-thon								−1
hero-athon		−1		−1			−1	
hero-thon								−1
soda-alicious		−1	−1	−1			−1	
soda-licious								−1

Table 26: Constraint violations for *-(a)thon*

As with *-(a)licious*, *soda-thon* will always be more likely than *hero-thon*, and *hero-thon* will always be more likely than *cactus-thon*, regardless of constraint weights (assuming non-zero weights).

6.4 Constraint weights

The target probabilities for the MaxEnt-HG model are repeated below, taken from the experiment. Note that hero-type words have been subdivided into *hero* (full V final) and *soda* (schwa final).

	Pr(alicious)	Pr(athon)
police	0.93	0.99
thirteen	0.80	0.98
cactus	0.45	0.79
hero	0.09	0.48
soda	0.04	0.10

Table 27: Target probabilities from experiment

The learner is provided with these probabilities, along with the candidates and constraint violations from the last section. For simplicity, other repairs (like epenthesis) aren't considered here, and surface forms are unambiguous, containing no hidden structure. When epenthesis is also considered as a possibility, using the approach to hidden structure learning in Pater et al. (2012), the learner still chooses the PCA analysis. As discussed in §7, surface forms from elsewhere in English contradict an analysis with general epenthesis or deletion.

The objective of the learner is to find a set of weights that maximizes the probability of observed forms. To find such a set of weights, I used the MaxEnt Grammar Tool (Wilson and George 2008). Weights were started at 0, and to prevent weights from climbing too high, an L2 (Gaussian) prior was used (Tychonoff and Arsenin 1977), with sigma^2 of 10,000. The model's weights are found using well-understood learning algorithms. Since learning defaults is as simple as learning a constraint weighting, no extra machinery is required.

The learned weights are in the table below.

Constraint	Weight	Constraint	Weight	Constraint	Weight
∗CLASH	2.66	RR RULES	16.56	UR = -athon	2.61
∗ə.V	1.81	FAITH(STRESS)	1.40	UR = -thon	0.45
∗HIATUS	1.50			UR = -alicious	0.85
∗LAPSE	0.85			UR = -licious	0.50

Table 28: Learned constraint weights

The table below shows the probabilities for each candidate in the learned grammar. The learned grammar closely matches the target probabilities. More importantly, it captures all of the target generalizations: schwa is more likely for *-(a)thon* across contexts; stress and final segment play a role in suffix selection; and RR-eligible stems are more likely to take *-licious* than RR-ineligible stems. The grammar captures the pattern for *-(a)licious* and *-(a)thon* with only faithfulness, markedness, and UR constraints. There are no constraints specifically for defaulthood, and there are no morphologically-specific markedness or faithfulness constraints.

	-(a)licious		-(a)thon		
	Target	Learned	Target	Learned	
pol$\overset{2}{\text{i}}$ce-al$\overset{1}{\text{i}}$cious	0.93	0.95	0.99	0.99	pol$\overset{1}{\text{i}}$ce-ath$\overset{2}{\text{o}}$n
pol$\overset{2}{\text{i}}$ce-l$\overset{1}{\text{i}}$cious	0.07	0.05	0.01	0.01	pol$\overset{1}{\text{i}}$ce-th$\overset{2}{\text{o}}$n
p$\overset{2}{\text{o}}$lice-al$\overset{1}{\text{i}}$cious (RR)	0.00	0.00	0.00	0.00	p$\overset{1}{\text{o}}$lice-ath$\overset{2}{\text{o}}$n (RR)
p$\overset{2}{\text{o}}$lice-l$\overset{1}{\text{i}}$cious (RR)	0.00	0.00	0.00	0.00	p$\overset{1}{\text{o}}$lice-th$\overset{2}{\text{o}}$n (RR)
thirt$\overset{2}{\text{ee}}$n-al$\overset{1}{\text{i}}$cious	0.80	0.71	0.98	0.99	thirt$\overset{1}{\text{ee}}$n-ath$\overset{2}{\text{o}}$n
thirt$\overset{2}{\text{ee}}$n-l$\overset{1}{\text{i}}$cious	0.00	0.04	0.02	0.01	thirt$\overset{1}{\text{ee}}$n-th$\overset{2}{\text{o}}$n
th$\overset{2}{\text{i}}$rteen-al$\overset{1}{\text{i}}$cious (RR)	0.00	0.09	0.00	0.00	th$\overset{1}{\text{i}}$rteen-ath$\overset{2}{\text{o}}$n (RR)
th$\overset{2}{\text{i}}$rteen-l$\overset{1}{\text{i}}$cious (RR)	0.20	0.16	0.00	0.00	th$\overset{1}{\text{i}}$rteen-th$\overset{2}{\text{o}}$n (RR)
cactus-alicious	0.45	0.38	0.79	0.79	cactus-athon
cactus-licious	0.55	0.62	0.21	0.21	cactus-thon
hero-alicious	0.09	0.12	0.48	0.45	hero-athon
hero-licious	0.91	0.88	0.52	0.55	hero-thon
soda-alicious	0.04	0.02	0.10	0.12	soda-athon
soda-licious	0.96	0.98	0.90	0.88	soda-thon

Table 29: Target and learned probabilities for MaxEnt model of -*(a)licious* and -*(a)thon*

The weights of the UR constraints capture the differences in baselines between -*(a)thon* and -*(a)licious*. For both suffixes, the default is the schwaful form. The degree of defaulthood differs across the two suffixes: for -*(a)thon*, there is large difference between the weight of UR =-athon and UR =-thon, making the schwaful form a strong default. For -*(a)licious*, the weights of the UR constraints are much closer, resulting in a weaker preference for the schwaful form.

In the learned grammar, ∗Clash and ∗Hiatus ensure that *police* occurs most with the schwaful form, and *hero* occurs most with the schwaless form. *Cactus* is between *hero* and *police*, since neither ∗Clash nor ∗Hiatus are at stake. Note that the effects hold for both suffixes, since both suffixes obey the same weighting of markedness constraints. *Soda-alicious* and *soda-athon* are strongly dispreferred by the grammar. Each incurs violations of both ∗ə.V and ∗Hiatus. *Hero-alicious* and -*athon*, on the other hand, only violate ∗Hiatus.

The interaction of RR and -*(a)licious* follows from the weighting of Clash over Faith(Stress). This interaction is only possible because RR and suffix allomorphy are considered in parallel. The difference between -*(a)licious* and -*(a)thon* comes from the high weight of RR Rules, which prevents retraction from primary stressed syllables (as in *thirteen-thon*).

For *thirteen*, the grammar assigns some probability to *-licious* without RR and *-(a)licious* with RR. The reason is the lack of general RR data in the learning data. The grammar has no way to know that RR only applies to resolve stress clash, or that it applies whenever there's a clash. Despite this, the grammar matches the observed distribution if we collapse over RR and non-RR candidates: 0.20 for *thirteen-licious* and 0.80 for *thirteen-alicious*.

Further predictions. Given the weights of ∗CLASH, ∗LAPSE, and ∗HIATUS, every alternating suffix in English (*-(o)rama*, *-(a)holic*, *-(e)teria*, etc.) should occur most often with schwa in stems like *police* and least often with schwa in stems like *hero*. This is assuming we control for other constraints, like those against segmental identity (segmental OCP).

This prediction follows from the fact that allomorphic variation is the result of the phonological grammar. While UR constraints can make a schwaful form more or less likely across the entire set of contexts, there is no way for a UR constraint to make a schwaful form more likely with *hero* than *cactus*, or more likely with *cactus* than *police*.

The constraint weights also predict that stress-final, vowel-final words, like *café*, will be between *cactus*- and police-type words. In *café*-type words, ∗CLASH and ∗HIATUS have competing demands for suffixation. For *café*, ∗CLASH prefers *-alicious* and *-athon*, while ∗HIATUS prefers *-licious* and *-thon*. Under the learned grammar, ∗CLASH is higher weighted than ∗HIATUS, so we expect more *café-alicious* than *café-licious*. Unfortunately, *café*-type words aren't well-attested in the corpus, and weren't tested in the experiment.

Given the constraint weights, RR will apply about 78% of the time in a phrase like *thirteen men*.

	Harmony	Exp(H)	Proportion
thirtéén men (no RR)	−2.66	0.07	22%
thírteen men (RR)	−1.40	0.27	78%

Table 30: Model's predictions for Rhythm Rule application

This isn't so far from what's observed in production experiments. Grabe and Warren (1995) report that stress clash is resolved about 85% of the time in a production experiment.

6.5 Relationship to English phonotactics

The model from the last section succeeds in capturing the distribution of *-(a)licious* and *-(a)thon*, and the weights were fitted using only the probabilities for licious- and thon-words. As discussed earlier, speakers don't have much evidence for the distribution of the two suffixes, and they certainly don't have access to the exact probabilities for each type of word. As a result, the fitting of the model isn't representative of how speakers actually acquire the phonological conditioning of the suffixes.

Under the LWC Hypothesis, allomorphy follows from the regular English phonological grammar. Speakers acquire the weights of markedness and faithfulness constraints in the course of acquisition of English, and the weights of UR constraints follow later.

This section shows that the weights of markedness constraints found for the conditioning of *-(a)licious* and *-(a)thon* match the weights we expect in the English phonological grammar. There are two types of evidence discussed here: raw counts from the English lexicon; and the weights of constraints in Hayes' (2012) phonotactic grammar. Both support the weights of the markedness constraints found by the model, even though the model's weights were determined exclusively from the distribution of *-(a)licious* and *-(a)thon.*

I finish the section by considering whether phonotactics alone are sufficient to account for the distribution of the suffixes. Recall that the suffixes have different phonological properties, especially with respect to stress. Perhaps these stress differences are responsible for the greater preference for schwa in *-(a)thon*. While English phonotactics can explain some of the phonological conditioning, they cannot account for the differences captured by UR constraints: that schwa is more likely in *-(a)thon* than *-(a)licious*.

Lexical counts. The weights above are reflected in the distribution of words in the English lexicon. Across English words, the constraints above with higher weights are less likely to be violated. This is shown in the table below, which presents the number of words that violate each constraint in the CMU pronouncing dictionary (Weide 1993). The counts only consider words that are at least three syllables long, since shorter words are unable to violate ∗LAPSE. I also exclude words that don't occur at least once in SUBTLEX-US, a corpus of English subtitles (Brysbaert and New 2009). Since any word that violates ∗ə.V also violates ∗HIATUS, the weights of the two constraints are combined in the first row.

Constraint	Weight in model	Number of violators (% of total words)
∗ə.V and ∗HIATUS	$3.31 = 1.81 + 1.50$	16 (<1%)
∗CLASH	2.66	1,597 (8%)
∗HIATUS (but not ∗ə.V)	1.50	2,792 (13%)
∗LAPSE	0.85	8,702 (41%)

Table 31: Number of 3+ syllable words that violate each constraint in CMU, out of 20,988 words.

Consistent with the constraint weights, the counts demonstrate that clashes are worse than lapses, and hiatus is worse when the left vowel is lax. The relationship between the constraint weights and proportion of violators in CMU is shown in the graph below. The graph plots the proportion of words in CMU that violate each constraint against the constraint weights. The weights are transformed by making them negative and applying the exponential function. Recall that the same function is used in MaxEnt Harmonic Grammar to convert harmony scores into probabilities.

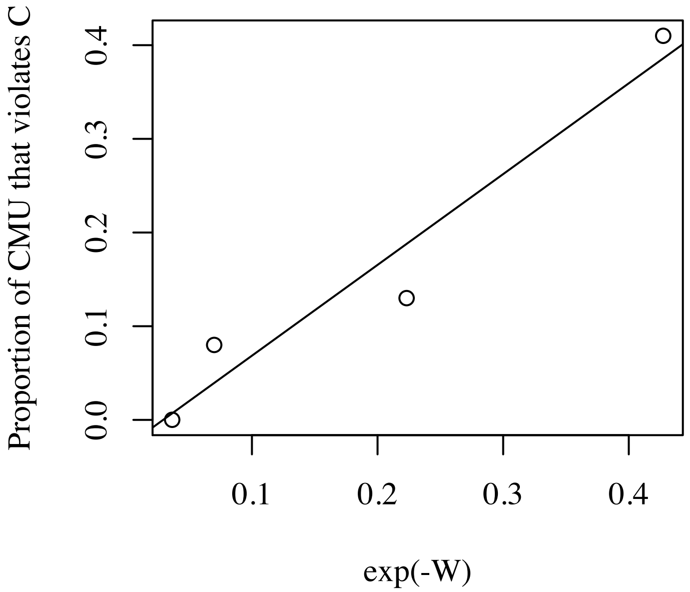

Figure 11: Exponentiated negative weight of each constraint vs. the proportion of 3+ syllable words in CMU that violate the constraint

Phonotactic grammar. The constraint weights learned for *-(a)licious* and *-(a)thon* also line up with those of an English phonotactic grammar: the BLICK grammar of Hayes (2012).[7] Like the model presented in this section, the BLICK grammar uses weighted constraints in MaxEnt Harmonic Grammar. The grammar includes more than 200 constraints, both machine learned and hand-picked from the literature by Hayes. The weights of these constraints were discovered using a large list of English words from the CMU pronouncing dictionary.

The lowest-weighted constraints from the suffix grammar have no weight in BLICK, either because they have a weight of zero (∗HIATUS) or because they weren't included in the BLICK grammar (∗LAPSE). The highest weighted constraints from the suffix grammar – ∗ə.V and ∗CLASH – both have relatively high weights in BLICK. Word-medial clashes are especially bad in BLICK, since they violate both a constraint against general stress clash, and a more specific constraint against medial stress clash.

While the phonotactic grammar mirrors the weights of the markedness constraints conditioning *-(a)licious*, it's unable to distinguish *-(a)licious* from *-(a)thon*. There is no constraint in BLICK that makes schwa more likely with *-(a)thon* than *-(a)licious*.

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[7] www.linguistics.ucla.edu/people/hayes/BLICK/

7 Arguments for PCA

Assuming that phonological constraints condition *-(a)licious* and other suffixes, there are many possible implementations of the conditioning. I treat the choice between *-licious* and *-alicious* as PCA: phonological constraints choose between two separate URs. Another possibility is that *-licious* and *-alicious* are derived from a single UR through epenthesis or deletion, or are the result of phonologically-conditioned blending. In this section, I argue against these alternatives. Although this section focuses on *-(a)licious*, these arguments apply equally to *-(a)thon*.

7.1 Not deletion or epenthesis

The best argument against a single UR account is that schwa alternations are limited to subset of English suffixes. If schwa were the result of a general process of epenthesis, we would expect it at every morpheme boundary in English, given the right phonological context. The suffixes below have no schwa, even with final-stressed, consonant-final stems. If the schwa in *police-alicious* is epenthetic, the same epenthesis rule should apply in *police-tastic*.

(52) Suffixes that never occur with a schwa, regardless of context

a. -wise:
police-wise   cactus-wise   *police-a-wise
b. -gate:
police-gate   cactus-gate   *police-a-gate
c. -zilla:
police-zilla   cactus-zilla   *police-a-zilla
d. -tastic:
police-tastic   cactus-tastic   *police-a-tastic

If the alternation were the result of deletion, we'd expect schwa deletion in the contexts that prefer the schwaless *-licious*. The suffixes below always occur with a schwa, even with unstressed V-final stems. These are the stems that strongly disprefer schwa in *-athon* and *-alicious*.

(53) Suffixes that always occur with schwa, regardless of context

a. -able:
delayable   carryable   *carry'ble (*[kæɹibl̩])
b. -ability:
delayability   carryabiliity   *carry'bility (*[kæɹibɪlɨɾi])

7.2 Not a minor rule

Another possibility is that schwa is the result of morpheme-specific epenthesis or deletion. There are two challenges for an account with a minor rule or morpheme-specific epenthesis.

First, hiatus- and clash-avoidance are not specific to the suffixes *-(a)thon* and *-(a)licious*. Using a minor rule or a morpheme-specific markedness constraint misses the fact that clash and hiatus are avoided across *all* of English.

Second, the rate of schwa realization differs between *-(a)licious* and *-(a)thon*. This means that we need either two separate morpheme-specific rules/constraints, or some way to limit the rate of epenthesis/deletion for one of the suffixes.

7.3 Not a blend

A final possibility is that *-(a)licious* is the product of blending. Under this analysis, *cactus-licious* is a combination of the words *cactus* and *delicious*.

(54) Examples of common blends

a. smoke+fog = smog
b. motor+hotel = motel
c. breakfast+lunch = brunch

There are four common properties of blends, all of which are contradicted by contemporary *-(a)licious* words. The properties of blends come from Plag (2003).

(55) Properties of blends from Plag (2003)

a. Blends are semantically compositional, involving meanings of both components.
b. Blends are more likely between words of the same syntactic category.
c. Blends resemble the prosody of their component words.
d. Blends are formed by combining subparts of two words.

According to Plag (2003), the semantics of blends resembles that of copulative compounds, such as *actor-director* and *writer-journalist*. In a blend like *boatel* (from *boat*+*hotel*), both components contribute meaning: a *boatel* is both a *boat* and *hotel*. However, a word created with *-(a)licious* needn't relate to deliciousness, in terms of either sexiness or tastiness. For most speakers, something that is *puppy-licious* is not delicious in any sense of the word.

(56) I went to the pound, and boy was it puppy-licious. (the pound had lots of puppies, and it was great)

Blend-like semantics does hold for early usages of *-(a)licious*, before it became a suffix. The suffix *-(a)licious* only attained suffixhood as recently as the 1990s. Zimmer (2006) shows that early uses of *-(a)licious* in the 1940s–1960s took it as a blend component. Blends were often only one segment removed from *delicious*, and described delicious things. Some examples are *tea-licious* (describing tea), *sea-licious* (describing shrimp), and *bee-licious* (describing honey). As shown by the COCA examples, modern usage allows a more diverse set of stems and meanings, including words like *puppy-licious*.

Since both parts contribute meaning, blends are typically formed from words of the same syntactic category, e.g. two nouns or two adjectives. This is not the case for *-(a)licious* – which disprefers adjectives. This is a weaker argument, however, since early *-licious* blends also occurred with nouns.

The next property of blends is that they resemble the prosody of their component words. For example, blends tend to be no longer than the longer of their two components (Plag 2003). This is not the case for words derived with *-(a)licious*, which are typically longer than both the stem and *delicious*. This holds for all of the disyllabic stems here (*turkey-licious*, *cougar-licious*). Again, this requirement held of early uses of *-(a)licious*, which tended to only contain vowel-final monosyllabic stems: *tea-licious*, *bee-licious*, *sea-licious*.

There are other prosodic requirements in blending (see Arndt-Lappe and Plag 2013 for example), although the literature is subject to disagreement. The easiest way to see the prosodic differences between *-(a)licious* and true blends is to compare them directly. In the examples below, I give attested blends between monosyllabic words and trisyllabic words. The trisyllabic words have the same stress pattern as *delicious*, but in the derived blends, schwa is disfavored.

(57) Attested blends

a. mock + martini = mocktini, *mock-a-tini
b. gay + gestapo = gaystapo, *gay-a-stapo
c. man + bikini = mankini, *man-a-kini

In the equivalent licious-words, the schwa is required.

(58) *-(a)licious* words

a. curve-a-licious, *curve-licious
b. hunk-a-licious, *hunk-licious
c. starch-alicious, *starch-licious

As a final example of prosodic differences, consider *delightful* and *delicious*. Both are adjectives with the same stress pattern. According to my own intuitions, blends with *delightful* don't take a schwa, while licious-words prefer one. There are a few wrinkles here. V-final words like *tea* pattern identically for both *delightful* and *delicious*, and some blends with *delightful* seem impossible (marked with a question mark), especially for polysyllabic words.

(59) *delightful* and *delicious*

a. dog: *dog-lightful*, *dog-alicious*
b. tea: *tea-lightful*, *tea-licious*
c. hunk: *hunk-lightful*, *hunk-alicious*
d. babe: *babe-lightful*, *babe-alicious*
e. police: ?*police-lightful*, *police-alicious*
f. booty: ?*booty-lightful*, *booty-licious*

The final property of blends is that they are commonly formed by concatenating subparts of two words. For example, *brunch* is formed from the onset of *breakfast* and the rhyme of *lunch*. In the corpus results, the majority (310/340) of licious-words are formed by taking a full, untruncated stem and adding *-licious* or *-alicious*.

It should be noted, however, that some *-licious* words really do resemble blends. About 10% of the licious-words in the corpus contain a truncated root. An example is *coalicious*, from *coalition* and *licious*. This word obeys the prosodic conditions for blends described above. The fact that words like this are still used suggests that *-licious* is currently leading a double life, transitioning from full blend component (as it was in the 1960s) to full suffix.

The conclusion is that licious-words on the whole are not blends. If they are blends, as commonly suggested, then they are blends that pattern differently with respect to semantics, syntax, and phonology. While it's possible that there are two types of blends, ones like *smog* and ones like *booty-licious*, it's clear that latter type are more suffix-like along every dimension.

8 Conclusion

This paper provided an in-depth case study of *-(a)licious* and *-(a)thon*, using both corpus and experimental data. These suffixes support the claim that PCA is driven by language-wide constraints, in a parallel model of phonology and morphology. The suffixes *-(a)licious* and *-(a)thon* are conditioned by ∗CLASH and ∗HIATUS, constraints that are synchronically active and well-motivated in English. The conclusion is that speakers extend their existing grammatical knowledge to new suffixes, choosing suffixal forms that avoid stress clash and hiatus.

The argument for parallelism comes from the interaction of suffix selection and the Rhythm Rule (RR). Stems that can avoid a clash by undergoing RR are less likely to occur with *-alicious*, the clash-avoiding form of the suffix. The connection between suffix selection and RR is further supported by differences between *-(a)licious* and *-(a)thon*. Suffixes that can trigger RR show a difference between RR-eligible and RR-ineligible stems, while suffixes that cannot trigger RR show none. These interactions require UR selection to have lookahead to phonological repairs.

Finally, the suffixes can be straightforwardly modeled with UR constraints in MaxEnt-HG. Such an account can model the variation present in the data, and its constraint weights can be learned using existing learning algorithms. This account can capture both the markedness conditioning of the suffixes, along with differences between the baseline rates of *-(a)licious* and *-(a)thon*. Moreover, the model's learned weights are reflected in the English lexicon and phonotactics.

9 Appendix: Experimental Items

This appendix presents the full results of the experiment, including fillers and individual proportions for the stems of interest.

Stem type	-(a)licious	-(a)thon	Final C/V	Stress pattern
acoustic	0.50 (0.02)	0.69 (0.02)	C	010
alaska	0.03 (0.01)	0.13 (0.01)	V	010
cactus	0.45 (0.02)	0.79 (0.02)	C	10
thirteen	0.80 (0.02)	0.98 (0.01)	C	12
hero	0.07 (0.01)	0.30 (0.02)	V	10
japanese	0.78 (0.02)	0.96 (0.01)	C	201
police	0.93 (0.01)	0.99 (0.01)	V	01
underwear	0.73 (0.02)	0.94 (0.01)	C	102

Table 32: Proportion schwa for each stem type (standard errors in parentheses)

hero-type	Pr(ə)	cactus-type	Pr(ə)	thirteen-type	Pr(ə)	police-type	Pr(ə)
chili	0.29	acid	0.82	antique	0.94	balloon	0.98
china	0.08	basket	0.69	berlin	0.98	cologne	0.98
cookie	0.37	decade	0.93	brunette	1.00	debate	1.00
cuba	0.06	gossip	0.78	caffeine	1.00	design	1.00
drama	0.14	magic	0.73	champagne	0.98	estate	0.95
hero	0.61	necklace	0.84	chinese	0.98	grenade	1.00
jackie	0.48	office	0.78	concrete	1.00	japan	0.97
menu	0.52	patrick	0.82	corvette	0.98	maroon	0.98
russia	0.09	pirate	0.72	routine	0.98	parade	1.00
zero	0.62	secret	0.79	thirteen	0.98	police	1.00
mean	0.32	mean	0.79	mean	0.98	mean	0.99
low	0.06	low	0.69	low	0.94	low	0.95
high	0.62	high	0.93	high	1.00	high	1.00

Table 33: Proportion schwa for each *-(a)thon* stem

hero-type	Pr(ə)	cactus-type	Pr(ə)	thirteen-type	Pr(ə)	police-type	Pr(ə)
chili	0.14	acid	0.39	antique	0.77	balloon	0.88
china	0.05	basket	0.38	berlin	0.86	cologne	0.98
cookie	0.09	decade	0.69	brunette	0.83	debate	0.90
cuba	0.03	gossip	0.32	caffeine	0.84	design	0.98
drama	0.02	magic	0.38	champagne	0.73	estate	0.90
hero	0.12	necklace	0.67	chinese	0.76	grenade	0.98
jackie	0.03	office	0.43	concrete	0.74	japan	0.94
menu	0.14	patrick	0.51	corvette	0.84	maroon	0.94
russia	0.05	pirate	0.33	routine	0.80	parade	0.91
zero	0.00	secret	0.37	thirteen	0.81	police	0.88
mean	0.07	mean	0.45	mean	0.80	mean	0.93
low	0.00	low	0.32	low	0.73	low	0.88
high	0.14	high	0.69	high	0.86	high	0.98

Table 34: Proportion schwa for each *-(a)licious* stem

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