Phonetic rhythm in American English *-ization*[*]

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Abstract

It is commonly assumed that *CLASH and *LAPSE evaluate syllable-sized constituents: a sequence of two adjacent stressed syllables ($\underline{\acute{\sigma}\acute{\sigma}}$) violates *CLASH, while a sequence of two stressless syllables ($\acute{\sigma}\underline{\sigma\sigma}\acute{\sigma}$) violates *LAPSE (see e.g., Prince 1983, Gordon 2002 for *Clash; Nespor & Vogel 1989, Green & Kenstowicz 1995, Gordon 2002 for *LAPSE). In this paper I argue, based on patterns of secondary stress in American English *-ization*, that *CLASH and *LAPSE should instead be evaluated with respect to normalized duration. I present supporting evidence from corpus, judgment, and production studies.

1. Introduction

It has been a common assumption, since at least Liberman & Prince (1977), that stress is the manifestation of linguistic rhythm. The term *rhythm* implies alternation, or the timed succession of weak and strong beats. In English, for example, rhythmic alternation can be found at the phrase level. In the phrase *twenty-seven Mississippi legislators* (Hayes 1995:28), there is an alternation of weak and strong beats at multiple levels of structure (1): every second syllable carries some level of stress, and every fourth syllable carries a stronger stress.

(1) Rhythmic alternation within a phrase (Hayes 1995:28)

```
                        x
x         x         x
x    x    x    x    x   x
x x  x x  x x x x   x x x x
```
twenty-seven Mississippi legislators

Alternation can also be found at the word level. Words like *reconciliation* demonstrate that there is a general trend towards rhythmic alternation in English words (though exceptions to this tendency, such as *expèllée*, certainly exist).

(2) Rhythmic alternation within a word (Hayes 1995:29)

```
      x
x     x
x   x x
x x x x x x
```
reconciliation

The term *alternation*, in turn, implies that a sequence of beats is spaced out over time. Weak and strong beats do not happen at once; a strong precedes a weak, which precedes a strong.

This paper addresses the question of how rhythmic spacing should be measured. Current theories of stress propose different answers to this question. In constraint-based approaches to stress

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that assume feet (e.g. McCarthy & Prince 1993), constraints like PARSESYL require syllables to be parsed into feet, while constraints on foot form (like IAMB, requiring prominence to be foot-final) and constraints on foot alignment (like ALLFTLEFT, requiring each foot to coincide with the word's left edge) regulate the spacing, or *distance*, between the stresses. In constraint-based approaches to stress that eschew feet (e.g. Gordon 2002), constraints like *LAPSE (e.g. Nespor & Vogel 1989, Green & Kenstowicz 1995, Gordon 2002) and *CLASH (e.g. Prince 1983, Gordon 2002) regulate the distance between stressed and stressless syllables directly. *LAPSE (3) prohibits stresses from occurring too far apart, while *CLASH (4) prohibits stresses from occurring too close together.

(3) *LAPSE: assign one * for each sequence of two adjacent stressless syllables.

(4) *CLASH: assign one * for each sequence of two adjacent stressed syllables.

These approaches are superficially different, but they share something fundamental: both calculate distance over units of formal structure (syllables and feet). This paper explores an alternative: rhythm is calculated not over units of formal structure but over normalized duration. Evidence for this alternative comes from suffixal stress in American English *-ization* (see Stanton 2019 for a similar case study from *-ative*). In these forms, stress on *-ize* is variable: one can pronounce *realization* as [ˌɹiləˈzeɪʃən] or [ˌɹiˌlaɪˈzeɪʃən], *culturalization* as [ˌkʌltɚɹəlɪˈzeɪʃən] or [ˌkʌltɚɹəˌlaɪˈzeɪʃən] (transcriptions from the Oxford English Dictionary). I claim that this variation is, at least in part, governed by rhythm: *-ize* stress becomes more likely as the suffix's distance from the rightmost stem stress increases. To give an example: a word like *culturalization* (with a stem-final stress lapse) is more likely to bear *-ize* stress than a word like *realization* (without one). I show that the metric of distance speakers use when deciding whether or not to stress *-ize* must reference duration in a more direct way than is generally assumed by theories of stress.

1.1. Roadmap

Section 2 of this paper introduces stress in *-ization*, provides a preliminary analysis of suffixal stress, and documents the existence of rhythmic effects in data from the Oxford English Dictionary (OED). Section 3 advances the hypothesis that *-ize* stress is sensitive to duration. Section 4 provides evidence from a forced-choice task that supports this hypothesis, and Section 5 develops the proposal. Section 6 presents evidence from a production task that is consistent with the proposal. Section 7 discusses further evidence consistent with the idea that (normalized) duration plays a role in stress assignment, both in English and elsewhere, and Section 8 briefly concludes.

2. Stress in *-ization*

Words ending in *-ization* vary in whether or not *-ize* bears stress. A look at the OED makes this clear: some words are transcribed with stress on *-ize* (e.g. *solarization*), others are transcribed without stress on *-ize* (e.g. *fascization*), while still others are transcribed with both variants (e.g. *serialization*). Before focusing on this variation, it is necessary to review more general properties of stress in *-ization* to understand what conditions stressing and destressing of *-ize*.

2.1. Background

For analysis, it is useful to separate words that end in *-ization* into two domains: the stem domain (all of the material that precedes *-ization*) and the suffixal domain (composed of *-ize* and *–ation*). I illustrate with *solarization* and *fascization* in (5).

(5) Division of *-ization* forms into stem and suffixal domains

solar – ize – ation fasc – ize – ation

stem *suffixal* *stem* *suffixal*

We need a few assumptions to illustrate why stress on *-ization* varies. I assume, for the purposes of this paper, that *-ize* stress is compelled by a suffix-specific constraint: STRESS$_{-ize}$ (6).[1]

(6) STRESS$_{-ize}$: assign one * if the suffix *-ize* does not bear stress.

To explain why *-ation* is consistently stressed in *-ization* forms, I assume that the combination of NONFINALITY (7) and STRESS$_{-ation}$ (8) mandate penultimate stress.[2] (For NONFINALITY, see Prince & Smolensky 2004.)

(7) STRESS$_{-ation}$: assign one * if the suffix *-ation* does not carry stress on one of its syllables.

(8) NONFINALITY: assign one * if the final syllable bears stress.

Satisfaction of STRESS$_{-ize}$, STRESS$_{-ation}$, and NONFINALITY creates a stress clash. I assume that *CLASH (9), defined for now with respect to syllables, militates against this configuration.

(9) *CLASH: assign one * for each sequence of two consecutive stressed syllables.

The preference for *-izátion* (vs. *-ízation*) is due to the ranking between STRESS$_{-ation}$ and STRESS$_{-ize}$; if STRESS$_{-ation}$ dominates STRESS$_{-ize}$ it must be *-ize* stress, not *-ation* stress, that varies. This variation is illustrated in (10) with a tableau for *serialization*.

(10) Tableau for *serialization*

sérial-ize-ation	STRESS$_{-ation}$	*CLASH	STRESS$_{-ize}$
☞ a. sèrializátion 200210		*	
☞ b. sèrializátion 200010			*
c. sèrialízation 200100	*!		

Here, (10c) is eliminated because no stress falls on either of *-ation*'s syllables. Candidates (10a) and (10b) tie because they each violate one constraint in the second tier: (8a) (with stress on *-ize* and *-ate*) violates *CLASH, while (10b) (with stress on only *-ate*) violates STRESS$_{-ize}$. Which candidate surfaces as optimal depends on the ranking of these two constraints. If *CLASH dominates STRESS$_{-ize}$, (10b) surfaces as the winner. If STRESS$_{-ize}$ dominates *CLASH, (10a) wins.

[1] It is also possible to assume that *-ize* carries an underlying stress and that a high-ranked faithfulness constraint, such as IO-IDENT[stress], compels this underlying stress to surface. A further possibility is that *-ize* bears a stress due to the activity of WEIGHT-TO-STRESS (Prince 1990): because the suffix contains a diphthong, it counts as a heavy syllable.

[2] There are other ways to compel a stress on the *-ate* of *-ation*. One would be to claim that the suffix contains a diphthong [eɪ], and that it carries a stress due to the activity of WEIGHT-TO-STRESS. A second would be to claim that words in *-ation* must carry a stress on one of the final two syllables of the word; this constraint could be expressed as *LAPSERIGHT$_{-ation}$ (for positional lapse constraints, see Gordon 2002; for arguments that positional lapse constraints need to be indexed to certain classes of forms see Stanton & Steriade 2014, *in prep*).

The question of interest, then, is whether or not we can predict when *-ize* will be stressed: is the variation between (10a) and (10b) conditioned by anything, or is it random?

2.2. Rhythmic effects in *-ization* stress

Expanding on Stanton (2019:7.2), I conducted a corpus study to verify that rhythmic factors are implicated in *-ization* stress. The corpus consisted of all relevant *-ization* forms in the OED as of February 2019 (n=858[3]); for analysis, only those forms with a U.S. English transcription were considered (n=681). The inner suffix was counted as "stressed" if *-ize* was transcribed with the diphthong [aɪ] and as "stressless" if *-ize* was transcribed with a reduced vowel, [ə] or [ɪ]. Cases like *relativization* and *serialization*, where both variants are recorded, represented the majority of tokens (544/681) and were also excluded to facilitate statistical analysis of the results, as it is not clear whether these variable tokens should be counted as "stressed" or "stressless".

The results (11) demonstrate a clear rhythmic effect. Stress on *-ize* is least frequent when it would result in clash with the stem (as in *àlcohòlìzátion*), more frequent when it would resolve *LAPSE violation (as in *chànnelìzátion*), and most frequent when it would resolve an *EXTLAPSE violation (as in *pèrsonalìzátion*). (*EXTLAPSE, or *EXTENDEDLAPSE, is a rhythmic constraint that disprefers sequences of three adjacent stressed syllables; see Gordon 2002.)

(11) Results from OED corpus study

Effect of *-ize* stress	Stressed *-ize*	Stressless *-ize*	% stressed
*CLASH violation	*àlcohòlìzátion* (n=18)	*párallèlization* (n=26)	40.9% (18/44)
*LAPSE satisfaction	*chànnelìzátion* (n=35)	*dichòtimizátion* (n=31)	53.0% (35/66)
*EXTLAPSE satisfaction	*pèrsonalìzátion* (n=24)	*cùlturalizátion* (n=3)	88.9% (24/27)

As shown in (12), a logistic regression shows that the difference between the *LAPSE and the *EXTLAPSE contexts is statistically significant. The dependent variable is whether or not *-ize* bears stress; the independent variable is rhythmic context, with *LAPSE as the baseline. Comparisons are therefore between *CLASH and *LAPSE as well as *LAPSE and *EXTLAPSE.

(12) Results of statistical analysis for OED data

Predictor	Coefficient	*z* value	Significant?
Intercept	0.12	–	–
Context: *CLASH	-0.49	-1.24	No ($p = .21$)
Context: *EXTLAPSE	1.96	3.00	Yes ($p < .01$)

What other factors might be relevant here? Perhaps frequency-related factors play a role. For example, if the *-ize* base of the *-ization* word is frequent, it could be the case that speakers are accustomed to hearing *-ize* stress associated with that lexical item, leading them to be more likely to stress *-ize* in the *-ization* form. It could also be the case that frequency of the *-ization* form impacts its likelihood to bear stress: perhaps more frequent *-ization* forms, for example, are less likely to

[3] The number of forms in the OED was actually 773. I report a higher number here because some stems have two stress patterns, e.g. *multimerization* can be 202-x10 or 020-x10. In such cases, variants are counted as separate stems.

bear *-ize* stress. (For more on frequency-related factors that impact the pronunciation of derived words, see Hay 2003; see also Collie 2007 for applications to English stress). To assess these possibilities, I first fit a logistic regression to the data whose predictors included only the frequency of the *-ize* base and the frequency of the *-ization* derivative. The frequency measures are from the OED's frequency bands, which assign words a frequency score of 0 through 8.[4] This model did not find a significant effect of either derivative frequency (p = .14) or base frequency (p = .10). Adding the rhythmic factor in (12) results in a significant improvement to the model (χ^2 (1) = 14.22, $p <$ .001), indicating that rhythm makes a contribution independent of frequency. Finally, I added the frequency-related factors to the model in (12). This larger model does not result in a better fit to the data (χ^2 (2) = 2.52, p = .28), so it is unlikely that frequency plays a role in predicting *-ize* stress. This finding should be treated with caution, however, as the numbers in (11) are small (and see Section 5 for evidence that frequency effects surface in production).

Another factor that might play a role has to do with the identity of the final consonant. Some forms ending in *-ize*, like *exorcise* and *Catholicize*, have a stem-final [s]. As the *-ization* derivatives of these forms violate a constraint on the co-occurrence of identical segments, *[s]...[s] (see Suzuki 1998 on the instantiation of the Obligatory Contour Principle as **x*...*x* constraints), speakers might prefer to lengthen the vowel in between them to [aɪ] in order to increase the time between the [s]s. This, however, is not the case in the dictionary data (though see Sections 4 and 5 for evidence that the nature of the stem-final segment is important in both judgment and perception tasks). Adding a predictor to the model encoding whether or not the stem-final segment is [s] does not result in an improved fit to the data relative to the model in (12) (χ^2 (1) = 1.10, p = .29).

While there have been no studies on the pronunciation of *-ization* words in natural speech, available evidence suggests that speaker productions match the OED trends. The data in (16) (n=298) are from Forvo, an online pronunciation dictionary. The dictionary was searched in 2/2019 for each *-ization* word in the OED. Native speaker status and *-ize* stress were determined by ear.

As is clear from (13), the rates of *-ization* stress are overall lower in the Forvo data, suggesting that the rate of *-ize* stress is inflated in the OED data (see Sections 4 and 6 for further evidence that speakers of American English generally disprefer stress on *-ize*). The trend, however, is the same: *-ize* stress is least frequent in the *CLASH context, more frequent in the *LAPSE context, and most frequent in the *EXTLAPSE context.

(13) Results from the Forvo corpus study

Effect of *-ize* stress	Stressed *-ize*	Stressless *-ize*	% stressed
*CLASH violation	*rèalìzátion* (n=4)	*tàblòidizátion* (n=21)	19% (4/25)
*LAPSE satisfaction	*fòssilìzátion* (n=49)	*demòbilizátion* (n=151)	24.5% (49/200)
*EXTLAPSE satisfaction	*àctualìzátion* (n=21)	*làbializátion* (n=51)	29.2% (21/72)

A statistical model of (13) does not find a significant difference between the rates of *-ize* stress in the *CLASH and *LAPSE contexts (p = .56), nor does it find a significant difference between the rates of *-ize* stress in the *LAPSE and *EXTLAPSE contexts (p = .06). This is likely due to the relatively small number of forms in the *CLASH and *EXTLAPSE context. As was true for the OED

[4] Frequencies are log-scaled and controlled for homonyms and other complexities; see the OED's discussion of their frequency measures (https://public.oed.com/how-to-use-the-oed/key-to-frequency/) for more.

data, adding frequency-related factors, namely the frequency of the *-ization* derivative and that of its *-ize* base, does not result in an improvement in model fit (χ^2 (2) = 0.61, p = .74), nor does adding a predictor differentiating [s]-final stems from all others (χ^2 (2) = 0.00, p = .98).

Rhythm, then, appears to affect how likely *-ize* is to bear a secondary stress in *-ization* forms. Other factors, such as frequency and the identity of the stem-final segment, do not have an effect in these data (though these results should be treated with caution, and cf. Sections 4-6).

3. Hypothesis

In what follows, I investigate the hypothesis that *-ize* stress in *-ization* is sensitive to normalized duration. The longer the stressless string between the rightmost stem stress and the stem boundary is, in relation to the entire word, the more likely *-ize* is to carry stress. To give an example: *-ize* stress is most common in *personalization*-type words because the post-stress material in *pérsonal* takes up a large percentage of the overall duration of *personalization*. By comparison, the post-stress material in *álcohòl* takes up a smaller percentage of the overall duration of *alcoholization*. Analytically, this amounts to a hypothesis that stress in *-ization* is governed by rhythmic constraints that can reference normalized duration, a more fine-grained metric than is typically assumed.

If this hypothesis is correct, trends in the dictionary data should mirror trends in the phonetics. As the number of syllables between the rightmost stem stress and *-ize* increases, so should the normalized duration of the post-stress material. This is expected given the findings in (11) and (13): the more syllables that follow the rightmost stem stress, the more likely *-ize* stress is. This prediction is diagrammed in (14): words like *àlcohòlizátion* should have a shorter post-stress duration than words like *chànnelizátion*, which should have a shorter post-stress duration than words like *pèrsonalizátion*.

(14) Different post-stress durations (in black) in *-ization* forms

a. V̀ C_0 -izátion (*àlcohò**l**izátion*): shortest
   V̀ **[C_0]** *izátion*

b. V̀ C_0V C_0 -izátion (*chà**nnel**izátion*): longer
   V̀ **[C_0V C_0]** *izátion*

c. V̀ C_0V C_0V C0 -izátion (*pè**rsonal**izátion*): longest
   V̀ **[C_0V C_0V C_0]** *izátion*

While this prediction might seem self-evident, there have been reports of lapse compression in the literature. Nespor & Vogel (1989:102), for example, report that speakers increase their speech rate in order to lessen the duration of a stress lapse. If compression is used as a way to ameliorate *LAPSE violations in American English, it could be the case that the duration of the post-stress material is shortened in (14c) such that it becomes close or equivalent to the duration of the post-stress material in (14b). This possibility means that the prediction that more material should be associated with more duration should be verified rather than assumed.

To know if this hypothesis is plausible, we need to know whether or not the trends observed in dictionary data correlate with the predicted trends in duration. We also need to know whether or not speakers' preferences and productions match these trends.

4. Experimental support: forced-choice

To test the hypothesis, I ran a set of experimental tasks. The forced-choice task discussed in this section asked participants to choose between *-ìzátion* and *-izátion* variants of the same form. The results of this task are best-modeled under the assumption that speakers are sensitive to normalized duration and use this knowledge when judging an *-ization* form.

4.1. Items and acoustic analysis

For the experiment, I recorded a single native speaker of American English producing *-ìzátion* and *-izátion* variants of forms that ended in *-ization*, all placenames or demonyms. The placenames themselves were recorded along with the *-ization* derivatives.

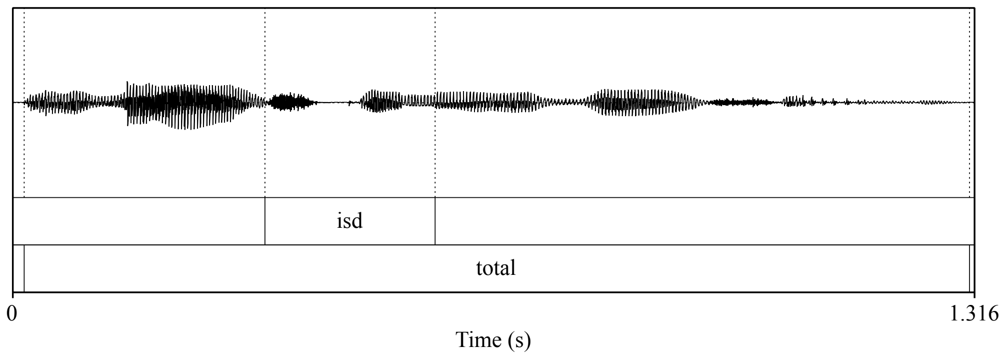
As shown in Table 1, these items included ten where *-ize* stress would introduce a violation of *CLASH with the stem (*Chadization*), ten where *-ize* stress would satisfy *LAPSE (*Brooklynization*), and ten where *-ize* stress would satisfy *EXTLAPSE (*Madisonization*). Within these categories, the consonants following the rightmost stem stress were varied by item; this variation was introduced to ensure that there was some durational variation among the items.

Table 1: *-ization* items, by rhythmic profile and interstress C(s)

*CLASH (n=10) Interstress C(s)	*LAPSE (n=10) Interstress C(s)	*EXTLAPSE (n=10) Interstress C(s)
Pràgueizátion [g]	*Ègyptizátion* [dʒ], [pt]	*Pròvidencizátion* [v], [d], [ns]
Quebècizátion [k]	*Wyòmingizátion* [m], [ŋ]	*Sènegalizátion* [n], [g], [l]
Chàdization [d]	*Cùbanizátion* [b], [n]	*Ìndianàpolisizátion* [n], [p], [l]
Ròmeizátion [m]	*Bròoklynizátion* [kl], [n]	*Antàrcticanizátion* [ɹ(k)t], [k], [n]
Japànizátion [n]	*Àustinizátion* [st], [n]	*Blòomingonizátion* [m], [ŋt], [n]
Brònxizátion [ŋks]	*Tèxasizátion* [ks], [s]	*Mèxicanizátion* [ks], [k], [n]
Vermòntizátion [nt]	*Phòenixizátion* [n], [ks]	*Mìchiganizátion* [ʃ], [g], [n]
Frànceizátion [ns]	*Alàskanizátion* [sk], [n]	*Òberlinizátion* [b], [ɹl], [n]
Bàsqueizátion [k]	*Rùssianizátion* [ʃ], [n]	*Màdisonizátion* [d], [s], [n]
Mìnskizátion [nsk]	*Ìcelandizátion* [sl], [nd]	*Ròchesterizátion* [tʃ], [st], [ɹ]

To measure the normalized duration of each interstress string, the distance between the rightmost stem stress and the end of the stem was divided by the total duration of the form. For each item, measurements were taken off of the *-ìzátion* productions. This means that in *Alàskanizátion*, for example, the interval between the offset of the stressed stem vowel and the onset of stressed [aɪ] (0.233 s) was divided by the overall duration of the form (1.294 s), yielding a normalized durational measurement of 0.18. Figure 1 illustrates how these measurements were taken in Praat (Boersma & Weenink 2021).

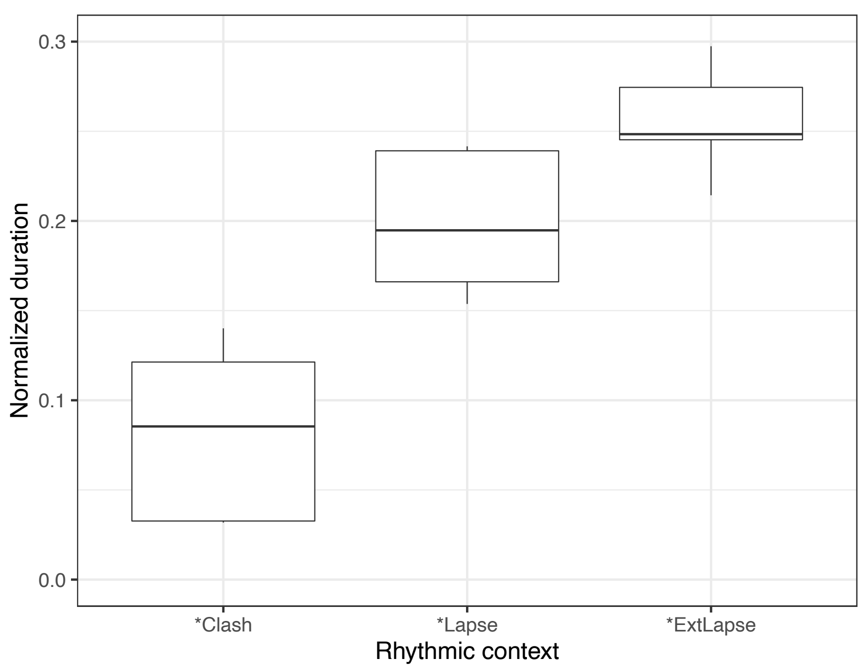
Figure 1: Calculating normalized duration in *Alàskanìzátion* (isd = interstress duration)



Normalized duration here is a relational measure: it is the proportion of the entire word taken up by the stressless string. In this, I follow earlier authors (notably Lunden 2013) in assuming that the right representation of duration in phonology is a normalized one, as this allows us to abstract away from issues like speech rate (see Section 5.1 for evidence that speech rate does not impact *-ize* judgments) and idiosyncratic variation in the durational properties of segments.[5]

Investigation of the durational properties of these forms reveals that the prediction regarding the association between normalized duration and segmental material is verified (Figure 2): the normalized duration of the interstress material is shortest in the *CLASH context (where there are no interstress stressless syllables), longer in the *LAPSE context (where there is one stressless syllable), and longest in the *EXTLAPSE context (where there are two).

Figure 2: Normalized duration by rhythmic context



[5] An open question here is if, in running speech, the normalizing duration ought to be the word or the phrase. The stimuli employed in this experiment are single words, so it is not possible to distinguish between these options at present.

This finding renders the first part of the hypothesis, outlined in Section 3, plausible: the broad trends discovered in the dictionary study correlate with properties of the productions.

4.2. Design

Stimuli were created from the forms in Table 1, differing only in suffixal stress. For example, the item for *Alaskanization* included two forms, *Alàskanizátion* and *Alàskanìzátion*. The words were presented in the frame *Prepare for the ___ of your vacation!* (e.g. *Prepare for the* ***Alaskanization*** *of your vacation!*), and participants were told that they were helping a travel company pronounce words in a new slogan. An illustration of what occurred at each trial is provided in Figure 3. First, participants clicked on the radio button associated with the placename and listened to a recording of that placename. After the placename played, the slogan was revealed, along with the two radio buttons that corresponded to the two pronunciations of the (bolded and italicized) test item. After both options had been played, participants were instructed to choose which option they preferred by clicking on either Option 1 or Option 2. The experiment then advanced to the next item.

The order of *-ìzátion* and *-izátion* variants was randomized by item and by participant; item order was also randomized by participant. Experiments were constructed with Experigen (Becker & Levine 2013).

Figure 3: Example of experimental item

This is a photo of a trail in Alaska.

Prepare for the ***Alaskanization*** of your vacation!

Option 1

Option 2

Which of these options do you prefer?

Option 1 Option 2

4.3. Participants

Fifty participants were recruited using Amazon's Mechanical Turk. Prerequisites for inclusion included a U.S. IP address and a HIT approval rate of greater than 95%. All participants indicated in a demographic questionnaire that they were native speakers of English, and no speakers were excluded from the analysis. Participants were compensated $1.50 for their time.

4.4. Results

Patterns in the data suggest that the hypothesis is correct. First, the distinctions among rhythmic categories are exactly what we would expect, given the data and acoustic results. These are laid out in (15). Rates of *-ize* stress are lowest in the *CLASH context (forms like *Quebecization*), higher in the *LAPSE context (forms like *Alaskanization*), and highest in the *EXTLAPSE context (forms like *Mexicanization*). Notice, however, that *-ize* stress was chosen at fairly low rates overall; this is consistent with the Forvo data (13), where *-ize* stress appeared to be the dispreferred option.

(15) Results by rhythmic context

Context (Example)	*-ize* stressed	*-ize* stressless
*CLASH (*Quebecization*)	34.9%	65.1%
*LAPSE (*Texasization*)	39.4%	60.6%
*EXTLAPSE (*Mexicanization*)	40.2%	59.8%

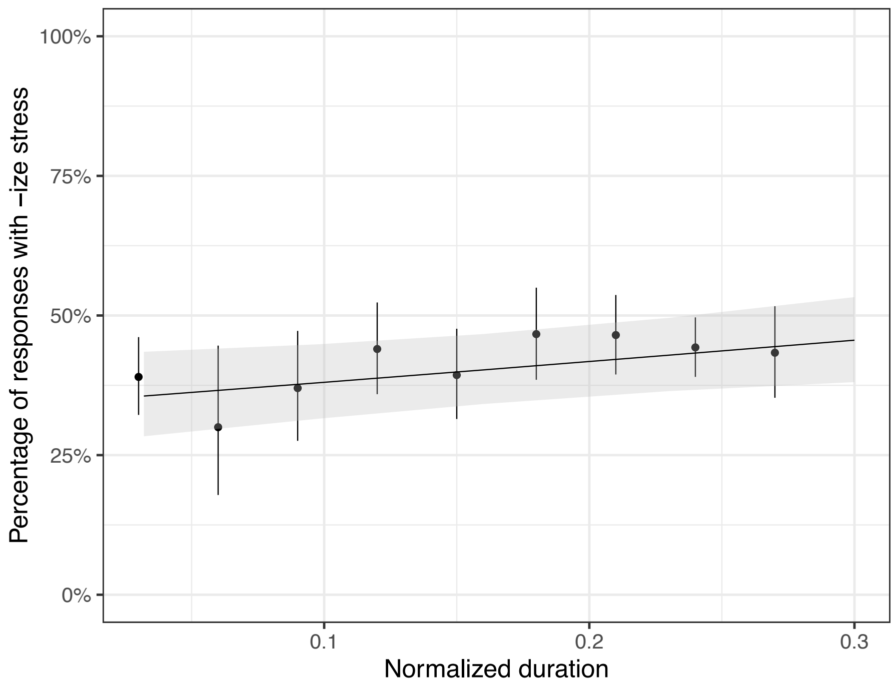
Turning our attention to the role of normalized duration in conditioning *-ize* stress, we find a similarly predictable result: there is a positive correlation between *-ize* stress and normalized duration. The longer the normalized duration of the post-stress material, the more likely participants were to prefer the form with *-ize* stress. Figure 4's *x* axis represents normalized duration. The raw results are represented as point ranges, where the point represents the percentage of responses preferring *-ize* stress and the line represents the 95% binomial proportion confidence interval. To aid readability, data were binned into intervals separated by a consistent measure. The best-fit line in Figure 4 was drawn using R's effects package (Fox 2003, Fox & Weisberg 2018, Fox & Weisberg 2019) and is based on the best-fit model in (16).

Interestingly, the statistics indicate that only duration provides a better explanation than does rhythmic category as to why the participant responses patterned as they did. The best-fit mixed-effects logistic regression model finds a significant effect of normalized duration as well as the identity of the final segment (/s/ vs. others). All models reported from this point forward, including (16), were fitted using the glmer function of R's lme4 package (Bates et al. 2015) and include a random intercept for participant. (A random effect for item was not included for convergence reasons.) Significance values are from lmerTest (Kuznetsova et al. 2017).

(16) Model with duration as a fixed effect

Factor	Coefficient	*z* value	Significant?
Intercept	-0.70	–	
Normalized duration	1.55	2.19	Yes ($p < .05$)
Final /s/	0.34	2.31	Yes ($p < .05$)

Figure 4: relationship between normalized duration and *-ize* stress



As is true for the corpus data, the frequency of the *-ization* derivative and its *-ize* base do not play a role in speaker responses (χ^2 (2) = 4.12, p = .12). The crucial finding here is that (16) has a lower AIC (1934.59 vs. 1936.53) and BIC (1955.83 vs. 1963.09) than does an otherwise equivalent model that substitutes rhythmic context for normalized duration. This indicates that a model that references normalized duration is a better fit to the data than is one that references rhythmic context; people's judgments more likely appealed to normalized duration than to rhythmic context.

We can take the following away from these results. First, phonetic rhythmic information plays a role in speakers' judgments about whether or not to stress *-ize* in *-ization* forms. Second, it's normalized duration that matters. The rhythmic category the forms belongs to (*CLASH, *LAPSE, *EXTLAPSE) only matters insofar as these categories are shorthand for normalized duration.

5. Analysis

I have suggested above that CON needs to contain rhythmic constraints that refer to normalized duration. This is not, however, the only possible interpretation of the results in Section 4. An equally probable hypothesis, given what we have seen so far, is that speakers are instead reacting to raw duration: the more milliseconds intervene between the rightmost stem stress and the stem's right edge, the more likely the listener is to prefer *-ize* stress (see Stanton 2019 for an instantiation of this proposal for *-ative*).

The raw and normalized duration hypotheses make different predictions regarding what might happen under different experimental conditions. Let us imagine a task, for example, in which half of the experimental items are played at the normal speech rate and half of the experimental items are slowed down. The raw duration hypothesis would predict a difference between listeners' reactions to the normal and the slowed items, as the slowed items would have longer interstress strings. The normalized duration hypothesis does not predict a difference: as the interstress string increases, so does the overall duration of the form. Varying the speech rate of the item changes the raw duration – but not the normalized duration – of the interstress material.

Section 5.1 reports the results of such an experiment and shows that they support the normalized duration hypothesis. Section 5.2 analyzes the results of the forced-choice task in Section 4 using a maxent grammar (e.g. Hayes & Wilson 2008) and shows that the proposed analysis results in a relatively close fit to the data.

5.1. Distinguishing between hypotheses: a second forced-choice task

To distinguish between the raw duration and normalized duration hypotheses, I conducted a second forced-choice task. This forced-choice task used half of the *-ization* items from the original task in Section 4; these items are provided in Table 2 for reference. In all other ways (design, recruitment, payment), this second forced-choice task was identical to the first.

Table 2: Half of *-ization* items, by rhythmic profile and interstress C(s)

*CLASH (n=10) Interstress C(s)	*LAPSE (n=10) Interstress C(s)	*EXTLAPSE (n=10) Interstress C(s)
Quebècizátion [k]	*Ègyptizátion* [dʒ], [pt]	*Sènegalizátion* [n], [g], [l]
Chàdization [d]	*Cùbanizátion* [b], [n]	*Ìndianàpolisizátion* [n], [p], [l]
Ròmeizátion [m]	*Àustinizátion* [st], [n]	*Antàrcticanizátion* [ɹ(k)t], [k], [n]
Brònxizátion [ŋks]	*Tèxasizátion* [ks], [s]	*Mèxicanizátion* [ks], [k], [n]
Bàsqueizátion [k]	*Phòenixizátion* [n], [ks]	*Ròchesterizátion* [tʃ], [st], [ɹ]

For this experiment, two versions of each item were used. In one, both forms were presented at the normal speech rate. In the second, both forms were artificially slowed by 20% (using Praat Vocal Toolkit, Corretge 2012). 20% is enough slowing for the difference between the normal and the slowed items to be audible, but not enough for the slowed forms to sound unnatural.

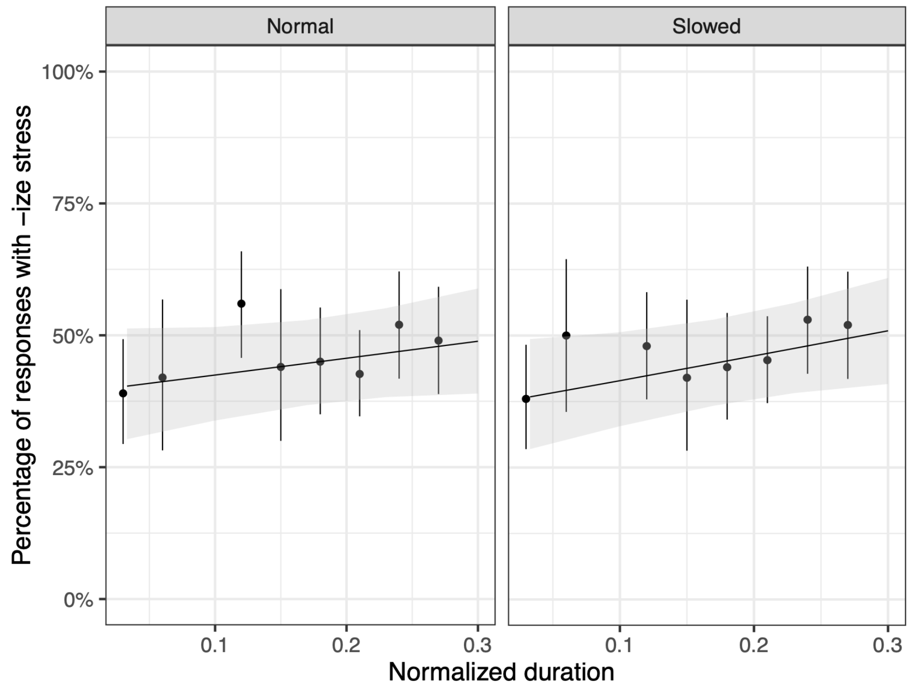
The prediction: if the raw duration hypothesis is correct, we should find a stronger preference for *-ize* stress in the slowed items. This is because there is a longer interstress string between the rightmost stem stress and the stem's edge. If the normalized duration hypothesis is correct, however, we do not expect to find such a difference.

The results are clear and support the prediction of the normalized duration hypothesis.

First, the results from the experiment show that the effect of normalized duration found in Section 4's forced-choice task replicates: normalized duration is a significant predictor of *-ize* stress, with a higher normalized duration leading to higher rates of *-ize* stress ($z = 2.23$, $p < .05$). The plot in Figure 5 breaks up the items by speech rate – I refer to the two categories as *normal* and *slowed* – and shows that the positive trend is evident in both subsets of the data. (Note that the absence of point ranges at intermediate positions in these plots means that there are no items included with a normalized duration falling in that range.)

Also evident in Figure 5 is the lack of a difference between the rates of *-ize* stress in the normal and slowed items: the trend lines are close to identical. (If the slowed items had *-ize* stressed at higher rates, we would have expected to see the trend line for the slowed items have a higher intercept than the trend line for the normal items.) This visual finding is borne out in the numbers: participants selected *-ize* stress for the normal items 53.6% of the time, and *-ize* stress for the slowed items 53.5% of the time. Given this, it is unsurprising that adding a predictor to the model for speech rate does not result in an improvement in fit (χ^2 (2) = 0.003, p = .95).[6]

Figure 5: relationship between normalized duration and *-ize* stress, by item type



As before, the model that appeals to normalized duration does better on measures of best fit than does an otherwise equivalent model that appeals to rhythmic context (1868.00 vs. 1940.85 for AIC; 1883.94 vs. 1962.10 for BIC). This result reinforces the suggestion that participants pay attention to normalized duration and not to rhythmic context. Rhythmic context matters only insofar as it is a stand-in for normalized duration.

5.2. Proposal

Defining versions of *LAPSE and *CLASH that refer to normalized duration is relatively simple, because normalized duration exists on a finite scale. If a stressless span has a normalized duration of 0, this means that it does not exist; it takes up the minimal amount of the form's overall duration as possible. If the stressless span has a normalized duration of 1, this means that it takes up the maximal amount of the form's overall duration: the form has no stresses.

I propose that the phonetic version of *LAPSE, *PHONETICLAPSE (*PHONLAPSE), assigns violations equivalent to the normalized duration of a stressless string (17). For the purposes of this paper, I assume that *PHONLAPSE applies to pairs of stress-bearing units (here assumed to be

[6] Other factors that do not result in an improvement in the fit of the model include base frequency, derivative frequency, and quality of the final segment (/s/ vs. others). In this way, the results of this second forced-choice task differ from the results of the first task; recall that the first task found a significant effect of the quality of the final segment.

vowels[7]), and that as such it only regulates the distribution of stress-bearing units with respect to one another. I assume that other constraints compel the presence of stress in the word (like CULMINATIVITY; Prince 1983) and that still others control the distribution of stresses with respect to word edges (constraints like *LAPSERIGHT, *LAPSELEFT, and NONFINALITY).

(17) *PHONLAPSE: for each span of stressless material between stressed vowels *i* and *j*, assign a violation score of *x* to that span, where *x* is equivalent to the span's normalized duration.

Here, higher values of *x* translate to more severe constraint penalties. This is what we want for a constraint that penalizes spans of stressless material as they grow longer.

I propose that the phonetic version of *CLASH, *PHONETICCLASH (*PHONCLASH), assigns violations equivalent to 1 minus the normalized duration of a stressless string (18). Similar to *PHONLAPSE, I assume that *PHONCLASH assigns violations to pairs of stress-bearing units, according to the duration between them.

(18) *PHONCLASH: for each span of stressless material between stressed vowels *i* and *j*, assign a violation score of 1-*x* to that span, where *x* is equivalent to the span's normalized duration.

Here, higher values of *x* translate to less severe constraint penalties. This is what we want for a constraint that penalizes spans of stressed material as they grow shorter.

For an example, let us consider *Alàskanìzátion*, whose stressless string has a normalized duration of 0.18. (I abstract away from the clash between *-ize* and *-ation*, as this is shared amongst all forms with *-ize* stress.) *PHONLAPSE assigns *Alàskanìzátion* a violation score of 0.18, while *PHONCLASH assigns *Alàskanìzátion* a violation score of 0.72. Now consider *Chàdìzátion*, whose stressless string has a normalized duration of 0.03. *PHONLAPSE assigns *Chàdìzátion* a violation score of 0.03, while *PHONCLASH assigns *Chàdìzátion* a violation score of 0.97. The *PHONLAPSE violation incurred by *Alàskanìzátion* (0.18) is greater than that incurred by *Chàdìzátion* (0.03); the *PHONCLASH (0.72) violation incurred by *Alàskanìzátion* is smaller than that incurred by *Chàdìzátion* (0.97). In this way, *PHONLAPSE penalizes longer stressless strings more harshly than it does shorter stressless strings, and *PHONCLASH does the reverse.

5.3. Application to experimental data

To determine if the constraints in (17-18) are sufficient to model the results of Section 4's forced-choice task, I fit a maxent grammar to the results using the Maxent Grammar Tool (Hayes et al. 2009). The structure of the input files is illustrated in Table 3. The first column contains the forms, the second column contains the two possible choices speakers were presented with, and the third column contains the frequency at which those forms were chosen in the experiment. For the purposes of this model, I included four constraints: *PHONLAPSE, *PHONCLASH, $\text{STRESS}_{\textit{-ize}}$, and *səz, the latter of which penalizes two coronal fricatives that are separated by a reduced vowel. This constraint is included due to the significant effect of Final /s/ in the model summarized in (16) and formalizes the intuition that a co-occurrence constraint between two coronal fricatives may hold more strongly when the fricatives are separated by a short vowel (e.g. [ə]) than it does when

[7] For the purposes of this paper, and for consistency with Stanton (2019), I assume that the stress-bearing unit is the vowel. Further work is necessary to determine if this is the correct measure to employ in the definition of *PHONETICLAPSE and *PHONETICCLASH, but see Stanton (2019) for evidence that the correct measure cannot be the normalized duration of the interstress syllables.

they are separated by a long vowel (e.g. [aɪ]). (See also Suzuki 1998:82, where identical elements separated by a single mora are penalized more harshly than identical elements separated by two.)

Table 3: structure of input file for the Maxent Grammar Tool

			*PHONLAPSE	*PHONCLASH	STRESS-*ize*	*səz
Alaskanization	*Alàskanìzátion*	.48	0.18	0.82	0	0
	Alàskanizátion	.52	0.31	0.69	1	0
Chadization	*Chàdìzátion*	.32	0.03	0.97	0	0
	Chàdizátion	.68	0.18	0.82	1	0
Texasization	*Tèxasìzátion*	.48	0.24	0.76	0	0
	Tèxasizátion	.52	0.35	0.65	1	1

The Maxent Grammar Tool discovers the weights in (19) for the four constraints.

(19) Constraint weights found by the Maxent Grammar Tool

Constraint	Weight
*PHONLAPSE	0.00
*PHONCLASH	2.86
STRESS-*ize*	0.00
*səz	0.35

Given these weights, the model achieves a decent fit to the experimental data. Table 4 shows a direct comparison between the expected and observed frequencies for each item, along with the difference between these two frequencies (in bold). The average deviation between observed and expected rates of *-ize* stress is .046, or 4.6%.

Table 4: comparison between expected (E) and observed (O) frequencies of *-ize* stress

Form	E	O	**Diff**		E	O	**Diff**
Alaskanization	0.41	0.48	**0.07**	*Mexicanization*	0.42	0.40	**0.02**
Antarcticanization	0.44	0.50	**0.06**	*Michiganization*	0.41	0.40	**0.01**
Austinization	0.40	0.40	**0.00**	*Minskization*	0.36	0.42	**0.06**
Basqueization	0.41	0.38	**0.03**	*Oberlinization*	0.40	0.40	**0.00**
Bloomingtonization	0.40	0.34	**0.06**	*Phoenixization*	0.49	0.52	**0.03**
Bronxization	0.48	0.52	**0.04**	*Pragueization*	0.38	0.36	**0.02**
Brooklynization	0.43	0.48	**0.05**	*Providenceization*	0.50	0.56	**0.06**
Chadization	0.40	0.32	**0.08**	*Quebecization*	0.41	0.30	**0.11**
Cubanization	0.41	0.34	**0.07**	*Rochesterization*	0.36	0.36	**0.00**
Egyptization	0.40	0.50	**0.10**	*Romeization*	0.39	0.42	**0.03**
Franceization	0.50	0.40	**0.10**	*Russianization*	0.41	0.44	**0.03**
Icelandization	0.42	0.34	**0.08**	*Senegalization*	0.42	0.48	**0.06**
Indianapolisization	0.52	0.52	**0.00**	*Texasization*	0.51	0.48	**0.03**
Japanization	0.41	0.46	**0.05**	*Vermontization*	0.42	0.34	**0.08**
Madisonization	0.43	0.50	**0.07**	*Wyomingization*	0.41	0.40	**0.01**

5.4. Discussion

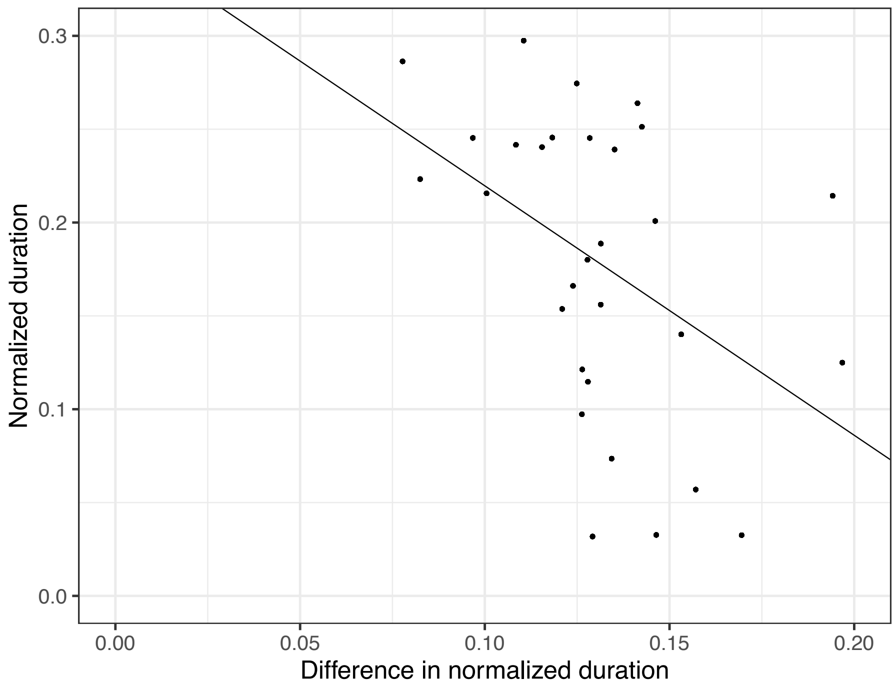
There are at least two aspects of this modeling exercise that merit further discussion.

One: while *PHONCLASH and *səz were assigned weight by the model, *PHONLAPSE and STRESS$_{\textit{-ize}}$ were not. This is equivalent to a claim that stress in *-ize* is governed by *PHONCLASH and *səz alone. It appears that defining and implementing *CLASH in this gradient, phonetically-informed way eliminates the need for suffix-specific STRESS$_{\textit{-ize}}$. With respect to *PHONLAPSE, this result shows that evidence for a phonetically-defined version of *LAPSE will need to come from phenomena other than secondary stress in *-ization*. One such phenomenon has already been discussed by Stanton (2019); secondary stress in *-ative* (falling on either *-ate* or *-ive*) can be seen as a lapse resolution strategy, with longer lapses correlated with higher rates of *-ate* stress.

Two: while the statistical models only include one measure of normalized duration – that of the stressless span between the rightmost stem stress and the stem boundary – the maxent model was fit to a fuller representation of the data, where both the variant with *-ize* stress and the variant without are associated with the normalized duration of their stressless strings. This means that *Alàskanìzátion* receives a *PHONLAPSE violation score of 0.18, for example, and *Alàskanizátion* receives a *PHONLAPSE violation score of 0.31. This discrepancy between the statistical modeling and the maxent model exists because it does not make sense, in a constraint-based model, to include the violation scores for only one candidate. Why should the speaker pay attention to the normalized duration of the lapse in *Alàskanìzátion*, but not to the normalized duration of the lapse in *Alàskanizátion*? The fact that the modeling exercise worked as well as it did indicates that the difference between the normalized duration of the two variants is also a reasonably good predictor of which forms are more or less likely to bear *-ize* stress: *-ize* stress occurs more frequently when the difference in normalized duration between the two variants is minimal.

Supporting this interpretation of the data is a negative correlation between the difference in the normalized durations of two variants and the normalized duration metric used throughout Section 4. This correlation is shown in Figure 6, where the trend line represents the fit of a linear regression (fit using R's lm function; $t = -19.13$, $p < .001$). As the normalized duration of a form increases, the difference in normalized duration between the two possible variants of that form decreases. To give an example: there is less difference in normalized duration between forms like *Mèxicanìzátion* and *Mèxicanizátion* than there is between forms like *Chàdìzátion* and *Chàdizátion*. In *Mèxicanìzátion*, the normalized duration of the stressless string is 0.30 while in *Mèxicanizátion* it is 0.41, leading to a difference in normalized duration of 0.11. In *Chàdìzátion* the normalized duration of the stressless string is .03 while in *Chàdizátion* it is 0.18, leading to a difference in normalized duration of 0.15. This difference between these two types of form could be an effect of lapse compression. In *Mèxicanizátion*, it is possible that the stressless material between the two stresses might be compressed; the speaker might speed up the speech rate of the stressless string, such that the normalized duration of the extended lapse in *Mèxicanizátion* approaches the normalized duration of the lapse in *Mèxicanìzátion*. Lapse compression might be expected to apply to a greater extent as the lapse grows longer, hence the negative correlation observed in Figure 6.

Figure 6: correlation between normalized duration and difference in normalized duration



If the difference between normalized duration in the two variants is correlated with the normalized duration measure used in Section 4, why use the latter to model the experimental results? The first reason is interpretability: it is intuitively easier to understand the results when they are framed in terms of "normalized duration" rather than "a difference in normalized duration between two candidate forms". The second is that use of the normalized duration metric results in a slightly better fit to the experimental data than does use of the difference metric. Recall that the AIC and BIC for the model reported in (16) are 1934.59 and 1955.83, respectively; the AIC and BIC measures for an otherwise equivalent model that substitutes the difference in normalized durations has an AIC of 1936.20 and a BIC of 1957.43. But these are small differences, and further work is necessary to determine which measure speakers actually use.

6. Experimental support: production

Results from the forced-choice tasks are consistent with the hypothesis that *-ize* stress is conditioned by the normalized duration of the string between the rightmost stem stress and the right edge of the word. A forced-choice task may, however, not be representative of how people speak, so it is important to verify that the results in Section 4 correlate with English speakers' productions. In this section I present the results of a production task, where participants were presented with a collection of *-ization* words and asked to say them aloud. The results of the production task are consistent with those of the forced-choice task: there is a positive correlation between rhythmic category and the rate at which speakers produce *-ize* stress. An additional finding from the is that not all speakers exhibit variation in *-ize* stress; most speakers consistently leave it stressless.

6.1. Design

For the production study, the stimuli were the same as those included in the forced-choice task (see Table 1). As was the case with the forced-choice task, participants were told that they were helping a travel company pronounce words with new slogans. First, participants heard a recording of the placename (e.g. *Quebec*). Then, participants were asked to read the slogan aloud (e.g. *Prepare for the* ***Quebecization*** *of your vacation*).

The experiment took place over the Zoom web conferencing platform, with the experimenter advancing from slide to slide once the participants produced the slogans. Participants' audio was recorded using their computer's microphone and they were compensated $10.00 for their time.

6.2. Participants

Fifty-seven participants were recruited for the study from Craiglist (a classified advertisement site), Facebook, and Twitter.[8] All but one indicated that they were native speakers of English from the United States. In addition to the one speaker who was not a native speaker of American English, six other participants were excluded due to the author's judgment that they were not being truthful about their language background. With these exclusions, fifty participants remained.

6.3. Results

The experiment yielded 1495 analyzable tokens. (The five unanalyzable tokens were from a single speaker whose Internet connection was unstable.)

Most productions (992/1495) did not involve rhythmic modification of the item. To understand what I mean by rhythmic modification, consider the form *Quebecization*. In the majority of cases (35/50), this form was pronounced as *Quebècizátion*, with stem stress in the intended place and no stress on *-ize*. Because productions of this type were so frequent, I assume that the default option for American English speakers is to leave *-ize* stressless (this is consistent with the Forvo data discussed in Section 2.2 and the results from the forced-choice task in Section 4).

The remaining 15 productions constitute a mix of rhythmic and non-rhythmic modification. One type of non-rhythmic modification is segmental change that does not affect the rhythmic profile of the form: *Quebècsizátion*, for example, instead of *Quebècizátion*. Another type of non-rhythmic modification includes some forms modified in multiple ways at once. One speaker, for example, produced the form as *Quèbecìzátion*. The combination of *-ize* stress and stem stress shift (*Quèbec* instead of *Quebèc*) means that, like *Quebècizátion*, the form exhibits perfect alternation.

The category of rhythmic modification includes forms like *Quebècnátion* (which has undergone deletion and segmental substitution, creating a clash) and *Quèbecizátion* (which has undergone stress shift, creating a lapse). There were, in total, four types of changes that participants employed which led to rhythmic modification. These were addition (Section 6.3.1), stem stress shift (Section 6.3.2), deletion (Section 6.3.3), and *-ize* stress (Section 6.3.4). Our interest will ultimately be in deletion and *-ize* stress, but the other two repairs are discussed here to provide a complete picture.

6.3.1. Addition

In cases that demonstrate addition, material is added to either a stem or a suffixal domain. Two types of addition that were common in the data include suffix doubling (e.g. *France**iz**ization*) and demonym formation (e.g. *Rom**an**ization*, instead of the expected *Romeization*). The 46 tokens that exhibited addition were not evenly distributed by rhythmic context: the majority of additions happened in the *CLASH context. In other words, addition in forms like *Bronxization* (yielding, for example, *Bronx**in**ization*) was more frequent than addition in forms like *Egyptization* (yielding, for example, *Egypt**iz**ization*) (20).

[8] Thanks to Lisa Davidson for posting my advertisement to her Twitter account.

(20) Addition by rhythmic context

Context (Example)	No addition	Addition	% addition
*CLASH (*Quebecization*)	*Bronxization* (n=456)	*Bronx**in**ization* (n=40)	10.3% (40/496)
*LAPSE (*Texasization*)	*Egyptization* (n=495)	*Egypt**iz**ization* (n=5)	1.8% (5/500)
*EXTLAPSE (*Mexicanization*)	*Michiganization* (n=498)	*Michigan**if**ication* (n=1)	.002% (1/499)

The skewed distribution of addition is independently interesting. Addition doesn't make sense from a rhythmic perspective: with *CLASH context forms like *Bronxization*, addition creates a lapse out of what could have been perfect alternation. But the limitation of addition to the *CLASH context tells us something about how long lapses can be. Speakers are willing, if infrequently, to take a form that could have had perfect alternation and change that to a form that includes a lapse. The lower rows of (20), however, show us that speakers are unwilling to insert material that would lengthen a pre-existing lapse.

Within the *CLASH context, errors are distributed fairly evenly across items. The most common type of addition (in 21 of 46 forms) was creation of a demonym from a placename (e.g. *Romanization*, *Vermontenization*, *Pragueinization*), a strategy that could be attributed to the large number of demonyms included among the stimuli. Suffix doubling was also common (occurring in 9 of 46 forms) and occurred randomly across items. The remaining cases of addition were idiosyncratic, including forms like *Romyization* (perhaps a misreading of the orthography, *Romeization*) and *Vermonitization* (insertion of a vowel into the stem-final consonant cluster).

6.3.2. Stress shift

In forms that exhibited stress shift, the stress of the stem was pronounced differently than the stem is pronounced in isolation. A common example of this type of error comes from the form *Egyptization*. In isolation, this word is produced as a trochee (*Égypt*); in the *-ization* derivative, however, many speakers pronounced it as an iamb (*Egýpt*). The 98 tokens that exhibit stress shift are concentrated in four items (21): *Egyptization* (produced as *Egỳptizátion)*, *Japanization (Jàpanizátion)*, *Icelandization (Ìcelàndizátion)*, and *Rochesterization (Rochèsterizátion*).

(21) Rates of stress shift by item

Item	No stress shift	Stress shift	% stress shift
Egyptization	17	32	66%
Japanization	27	21	46%
Icelandization	35	15	30%
Rochesterization	38	12	24%
Senegal	46	4	8%
Quebec	46	3	6%
Providence, Vermont	48	2	4%
Antarctica, Austin, Cuba, Michigan, Oberlin, Phoenix	49	1	2%
Mexico	48	1	2%

Why should stress shift occur mostly in these items? For *Egyptization* and *Icelandization*, the answer is straightforward. In both cases, there exists a related derivative, *Egýptian* and *Ìcelándic*, that bears the same stress as the stress-shifted form. Using the stress of *Egýptian* and *Ìcelándic*, rather than the stress of *Égypt* and *Íceland*, achieves lapse satisfaction in *Egỳptizátion* and *Ìcelàndizátion*. These cases can thus be thought of as pseudo-cyclic effects (see Steriade 1999 *et seq*.; Stanton & Steriade 2014, *in prep*; Stanton & Steriade 2020): using the stress of a lexically related form in these cases allows for the satisfaction of *LAPSE.

For *Japanization* and *Rochesterization*, the answers are less straightforward. For the case of *Japanization*, there exist derivatives with initial stress: *Jàpanése* and the less-frequent *Jápanìze*. It is unclear, however, why speakers should adopt this stress, because it is not accentually improving. One possibility is that some speakers know the form *Japanize* and use this to determine the stress of the *-ization* form; see Section 6.3.5 for discussion of the existence of these kinds of effects in the deletion and *-ize* stress. Finally, in the case of *Rochesterization*, I hypothesize that some speakers have a secondary stress on the second syllable of *Rochester* (thus the word is *Róchèster*, not *Róchester*, as produced by the recorded speaker). For the speakers with a secondary stress, the choice to promote the secondary stress to primary, and to demote the primary to zero stress, can be seen as a move to satisfy both *CLASH (**Róchèsterizàtion*) and *EXTLAPSE (**Róchesterizàtion*).

Stress shift is interesting but orthogonal to the questions of interest addressed here, which concerns the role of rhythm in the production of American English *-ization*. This is because the factors that govern stress shift are not rhythmic in nature but have more to do with lexical idiosyncrasies and the properties of lexical families.

6.3.3. Deletion

In the 159 tokens that exhibited deletion, segments from either the stem or the suffix were deleted. Deletion was not localized to particular places in the word: to give an example, pronunciations of *Madisonization* involving deletion included *Madonization*, *Madisization*, and *Madisonation*. There are two factors that appear to be involved in determining whether or not a form undergoes deletion. The first of these is rhythm: deletion is more common in the *EXTLAPSE context than in the *LAPSE context, and deletion is more common in the *LAPSE context than in the *CLASH context (22).

(22) Rhythmic distribution of deletion

Context (Example)	No deletion	Deletion	% deletion
*CLASH (*Quebecization*)	*Bronxization* (n=482)	*Bronxation* (n=14)	2.8% (14/496)
*LAPSE (*Texasization*)	*Texasization* (n=454)	*Texization* (n=46)	9.2% (46/500)
*EXTLAPSE (*Mexicanization*)	*Bloomingtonization* (n=400)	*Bloomingtization* (n=99)	19.8% (99/499)

Given the effects observed in the forced-choice task, the results in (22) are unsurprising. As the normalized duration between the rightmost stem stress and the suffixal domain increases, speakers are more likely to delete material, thereby reducing the normalized duration.

The other factor that appears to determine whether or not a form undergoes deletion is the quality of the final segment: /s/ versus others. As is clear from (23), forms with a final /s/ (like *France*, *Texas*, and *Indianapolis*) are significantly more likely to undergo deletion than are forms that end with a different segment ($p < .001$, Fisher's Exact Test). Deletion can thus be seen as a strategy to repair a violation of *səz: instead of lengthening the vowel between the two sibilants, speakers get rid of one of the sibilants. This is independently interesting, as segmental co-occurrence constraints are usually satisfied through modification rather than deletion.

(23) Distribution of deletion according to word-final segment: /s/ versus others

Stem-final segment	No deletion	Deletion	% deletion
/s/	*Texasization* (n=232)	*Texasation* (n=67)	22.4% (67/299)
Another segment	*Mexicanization* (n=1104)	*Mexicazation* (n=92)	7.7% (92/1196)

It is possible, of course, that these two factors are confounded: perhaps the majority of /s/-final stems occur in the *EXTLAPSE context. This point is addressed in Section 6.3.5.

6.3.4. *-ize* stress

Of the four possible forms of rhythmic modification, the most common was *-ize* stress, occurring in 226 of 1496 items. It is worth noting however that *-ize* stress, while common, was not evenly distributed among speakers. Two speakers consistently stressed *-ize* while thirty-three speakers never did, meaning that variation in *-ize* stress was exhibited by only fifteen of the fifty speakers who participated in the experiment.

Nevertheless, there were patterns in the data. First, *-ize* stress was distributed unevenly across rhythmic contexts: *-ize* stress in the *CLASH context was less common than *-ize* stress in the *LAPSE context, which was less common than *-ize* stress in the *EXTLAPSE context (24). This pattern, where the rate of *-ize* stress increases from the *CLASH to *LAPSE to *EXTLAPSE contexts, mirrors those found in the OED data, the Forvo data, and the forced-choice task.

(24) Rhythmic distribution of -ize stress

Context (Example)	No *-ize* stress	*-ize* stress	% *-ize* stress
*CLASH (*Quebecization*)	*Quebècizátion* (n=447)	*Quebècìzátion* (n=49)	9.9% (49/496)
*LAPSE (*Texasization*)	*Tèxasizátion* (n=416)	*Tèxasìzátion* (n=84)	16.8% (84/500)
*EXTLAPSE (*Mexicanization*)	*Mèxicanizátion* (n=406)	*Mèxicanìzátion* (n=93)	18.6% (93/499)

As was the case with deletion, -ize stress is also more likely to happen in forms with an /s/-final stem (25), though this difference is not quite significant (p = .053, Fisher's Exact Test). The trend is however consistent with what was observed in the forced-choice task: a stem-final /s/ causes speakers to be more likely than usual to prefer a form with *-ize* stress.

(25) Distribution of deletion according to word-final segment: /s/ versus others

Stem-final segment	No deletion	Deletion	% deletion
/s/	*Texasization* (n=250)	*Texasization* (n=49)	16.3% (49/299)
Another segment	*Mexicanization* (n=1019)	*Mexicanization* (n=177)	14.8% (177/1196)

Overall, the trends that exist in *-ize* stress production mirror exactly those trends that were observed in dictionary data and in the forced-choice tasks. This finding supports an assumption, implicit throughout the first part of the paper, that dictionary data and forced-choice tasks are valid ways of accessing speaker intuition.

6.3.5. Modeling rhythmic repair

Deletion (Section 6.3.3) and *-ize* stress (Section 6.3.4) have something in common: both act to reduce the distance between the rightmost stem stress and the suffixal stress. They accomplish this differently – deletion brings the rightmost stem stress closer to the suffixal stress, while *-ize* stress brings the suffixal stress closer to the rightmost stem stress – but both repairs can be seen as part of a conspiracy to reduce the normalized duration of the stressless span. Because of this similarity, I refer to them together as rhythmic repair.

To make this conspiracy explicit, consider (26). Let us assume that a speaker is presented with the form *Madisonization* and high-ranked *EXTLAPSE forbids them from producing this form as the default *Màdisonizátion* (26c). (I use syllable-based rhythmic constraints here for ease of exposition.) I consider two possible repairs here: stressing *-ize* (which introduces a stress clash with *-ation*, leading to a violation of *CLASH) (26a), and deleting part of the material between the two stresses, violating MAX (McCarthy & Prince 1995, (26b)).

(26) Conspiracy of repairs for *EXTLAPSE

Madisonization	*EXTLAPSE	*CLASH	MAX
☞ a. Màdisonìzátion 200210		*	
☞ b. Màdonizátion 20010			*
c. Màdisonizátion 200010	*!		

The choice between these two repairs depends on the ranking of *CLASH and MAX. If *CLASH dominates MAX, the speaker deletes segments so as to move the two stresses closer together. If MAX dominates *CLASH, then the speaker stresses *-ize*, adding a new stress to reduce the distance between the rightmost stem stress and the suffixal stress.

Given that these two repairs perform the same function, we can model them together. To do this, I created a subset of data that excludes all forms exhibiting addition or stress shift. I fit a mixed effects linear regression model to the remainder of the data. The model asks the following question: which factors influence whether or not a form exhibits rhythmic repair? I included the following predictors in the model: rhythmic context (with *LAPSE as the baseline), identity of the final segment (/s/ vs. others), frequency of the *-ization* derivative, and frequency of the *-ize* base. (For consistency with the previous models, the only random effect included in the model is a random intercept for participant.) We see in (27) that all four factors have significant effects.

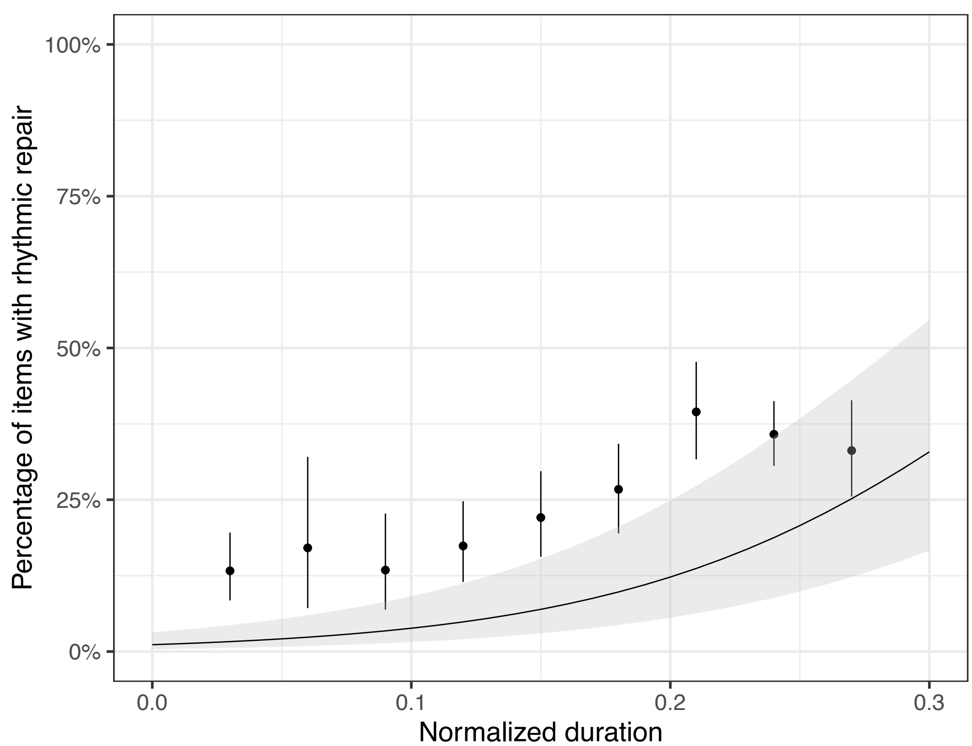
(27) Results of statistical model for rhythmic repair

	Factor	Coefficient	*z* value	Significant?
a.	Intercept	-2.67	–	
b.	Rhythmic context: *CLASH	-1.28	-4.74	$p < .001$
c.	Rhythmic context: *EXTLAPSE	1.18	5.18	$p < .001$
d.	Final /s/	1.92	8.07	$p < .001$
e.	Derivative frequency	-0.62	-2.46	$p < .05$
f.	Base frequency	0.46	2.10	$p < .05$

The negative coefficient for (27b) shows us that the overall rate of *-ize* stress is lower in the *CLASH context than it is in the *LAPSE context. The positive coefficient for (27c) shows us that the overall rate of *-ize* stress is lower in the *LAPSE context than it is in the *EXTLAPSE context. The positive coefficient for (27d) shows us that if the stem ends with an /s/, rhythmic repair is more likely to happen than if the stem ends with any other consonant. The effects of base frequency and derivative frequency, while both significant, go in opposite directions. The negative coefficient for (27e) shows us that, as the derivative becomes more frequent, it becomes less likely that it will exhibit *-ize* stress. The positive coefficient for (27f), in turn, shows us that as the *-ize* base becomes more frequent, the *-ization* derivative is more likely to exhibit *-ize* stress.

An important question to ask, given the questions at issue in this paper, is whether or not substituting a measure of normalized duration for rhythmic context results in a better fit to the data than the model in (27) achieves. But such a measure is difficult to obtain: participants were not exposed to recordings of the *-ization* forms like the participants in the forced-choice task were, and we cannot assume that the speaker who contributed their recordings to the forced-choice task is representative of the population as a whole. If we model the results using these existing measures, however, we find the following. Unsurprisingly, there is a positive correlation between the rate of rhythmic repair: as normalized duration increases, so does the rate of rhythmic repair (Figure 7).

Figure 7: relationship between normalized duration and rhythmic repair



If we substitute normalized duration for rhythmic context in (27) (leaving all other aspects of the model identical), the result is a model that finds significant effects for all four factors. The effects of Final /s/, Base frequency, and Derivative frequency are qualitatively identical to those in (27), and the effect of normalized duration is significant at $p < .001$. Goodness of fit measures point to the model in (27) being a better fit to the data (AIC: 872.43 vs. 885.43; BIC: 908.80 vs. 916.60).

This appears to contradict the results in Sections 4 and 5, which point to the primacy of normalized duration over rhythmic context, but it is hard to know what to make of this discrepancy. This is because it is unclear whether nor not modeling the results of the production experiment using measurements of items from a separate experimental task is a justifiable decision to begin with.

7. Broader evidence for phonetic rhythm

This paper has argued for a particular conception of phonetic *LAPSE and *CLASH based on data from American English *-ization*. One possible objection to the conclusions drawn here is that what we have observed might just be an effect specific to *-ization*. This is unlikely, for two reasons. One is that similar patterns arise in *-ative* (Stanton 2019): the greater the distance between the rightmost stem stress and *-ative*, the more likely speakers are to prefer secondary stress on *-at-*. The second is that words ending in *-ization* and *-ative* are infrequent and children would likely hear them only rarely. In the OED, the average frequency bin for a word ending in *-ization* or *-ative* is 2, meaning that they occur less than .01 times per million words. Unsurprisingly, they are uncommon in the CHILDES Parental Corpus (Li & Shirai 2000, MacWhinney 2000), where we find three *-ization* (*pluralization*, *specialization*, *civilization*) and zero *-ative* tokens, from a total of 2,579,966. Given the rarity of these forms, it is unlikely that children would acquire the secondary stress patterns documented here and in Stanton (2019) with reference to *-ization* and *-ative* forms alone.

In this section I discuss further potential evidence for phonetically defined rhythmic constraints. Section 7.1 focuses on potential evidence in English, discussing possible phonetic effects in the English rhythm rule (Hayes 1986, Beames 2020) as well as post-tonic syncope (Hooper 1978, Polgárdi 2015). Section 7.2 focuses on potential evidence in other languages, including the acceptability of secondary stress in Russian compounds (Gouskova & Roon 2013) and the distribution of secondary stress in longer Finnish words (Karvonen 2008).

7.1. Potential sources of evidence in English

The English rhythm rule (Liberman & Prince 1977, Prince 1983, Hayes 1984, *a.o.*) is a phrasal process in which primary stress retracts to avoid a stress clash. The rhythm rule applies most frequently given a stress-final first word and a stress-initial second word (e.g. *bàmbóo trúmpets* → *bámbòo trúmpets*) and less frequently given a stress-medial or stress-final second word (e.g. *bàmbóo viólas*, *bàmbóo trombónes*). For stress to retract, there must be a stress already residing in the target position of retraction: *compléte trúmpets*, for example, cannot be *cómplete trúmpets* because the initial syllable of *compléte* does not bear any degree of stress. The rhythm rule is subject to syntactic limitations, discussed in more detail by Liberman & Prince (1977), among others.

While it is typically assumed that the rhythm rule operates on a syllabic representation, Hayes (1984:70-73) posits that what conditions the rhythm rule is not the number of syllables between the stresses but rather the duration between them. In support of this hypothesis, Hayes notes a difference in intuition regarding retraction in the phrases *Kòrbél whískey*, *Kòrbél tequíla*, and *Koòbél champágne*. Hayes claims that retraction is most acceptable in *Kòrbél whískey*; this is expected, given that *whískey* is stress-initial. He claims that, in addition, retraction in *Kòrbél tequíla* seems more likely than retraction in *Kòrbél champágne*. This is not expected under a syllabic formulation of the rhythm rule, because in both cases the primary stress in the second word is peninitial. Hayes proposes that the greater likelihood of retraction in *Korbél champágne* is due to the fact that there is more material before the second-word stress in champagne ([ʃæmp]) than there is before the second-word stress in tequila ([tək]).

Hayes does not, however, back up this intuition with data. To fill this gap, Beames (2020) conducted an experiment with the aim of determining if the varying the segmental material before the second stress affects the rate at which the rhythm rule applies. Beames's stimuli consisted of all possible combinations of a list of first and second words, provided in (28). In each case, the first word was cast as an adjective and the second was cast as a noun. Beames also included fillers, which included phrases beginning with the trochaic *complete* as well as phrases ending with iambic forms such as *mistake*. These fillers were included to ensure that participants adhered to the basic principles of the rhythm rule and are not discussed further here. Each combination of words was embedded within a larger carrier phrase (e.g. *when you least expect it, bamboo strikes*), which participants were asked to read aloud.

(28) Stimuli for Beames's rhythm rule experiment (adapted from Beames 2020:5)

Word 1 (Orthography / IPA)	Word 2 (Orthography / IPA)
bamboo / [bæ̀mbú] *concrete* / [kɑ̀nkɹít] *fifteen* / [fiftín]	*likes* / [laɪks] *bikes* / [baɪks] *strikes* / [stɹaɪks] *aches* / [eɪks] *flakes* / [fleɪks] *wakes* / [weɪks] *cakes* / [keɪks] *rakes* / [ɹeɪks] *fakes* / [feɪks]

Beames found a modest effect of segmental material, summarized in (29). The rate of retraction is highest when the second word begins with a cluster: this is the case for phrases like *bamboo strikes* or *fifteen flakes*. Retraction is less frequent when the second word begins with an obstruent (as in *bamboo cakes* or *concrete bikes*), and less frequent still when the second word begins with a vowel (as in *fifteen aches*) or a sonorant (as in *bamboo rakes*). The effect thus goes in the direction we'd expect, given the discussion in this paper: assuming that a cluster onset is longer than an obstruent onset, which is longer than a sonorant onset (see Stanton 2019 for some evidence to support this assumption), the pattern here is one in which the rhythm rule applies more frequently when there is less time between the two stresses.

(29) Effect of segmental content on retraction

Segmental context	Retraction	No retraction	% retraction
V	*bámbòo áches* (n=38)	*bàmbóo áches* (n=72)	34.5% (38/110)
R	*bámbòo rákes* (n=118)	*bàmbóo rákes* (n=221)	34.8% (118/339)
O	*bámbòo cákes* (n=119)	*bàmbòo cákes* (n=217)	35.4% (119/346)
CC	*bámbòo stríkes* (n=88)	*bàmbòo stríkes* (n=137)	39.1% (88/225)

The comparisons among categories are not statistically significant (though a comparison between the V&R and O&CC effects is: $p < .001$, mixed effects logistic regression), meaning that further work is necessary to confirm the existence of phonetic rhythmic effects in the rhythm rule. But the effect is consistent with the patterns that have been observed in *-ative* (Stanton 2019) and *-ization*.

More possible evidence for phonetic rhythm in English comes from post-tonic syncope. It has been known since at least Hooper (1978) that post-tonic syncope is rhythmically conditioned: syncope can only occur when it does not result in a stress clash. The adjective *séparate* can syncopate to *séprate*, but the verb *séparàte* cannot syncopate to *sépràte*. Polgárdi (2015) casts English post-tonic syncope as a form of lapse resolution: it acts to reduce the number of syllables between two stresses or between a stress and the word's right edge. Given this characterization, along with the possibility of observing syncope in a multitude of different rhythmic contexts (e.g. *séparable* → *séprable*, *sèparabílity* → *sèprabílity, séparableness* → *séprableness*), English post-tonic syncope seems ripe for re-investigation along the lines detailed in this paper.

7.2. Potential sources of evidence outside English

Secondary stress does not usually occur in Russian but can be variably realized in compounds or in certain loan prefixes (Avasenov 1964, Yoo 1992, Gouskova & Roon 2013). Thus the compound [bʲitòn-ə-mʲiʂálkə] 'concrete mixer' (Gouskova & Roon 2013:393) can be realized with or without the secondary stress marked on the left half of the compound.

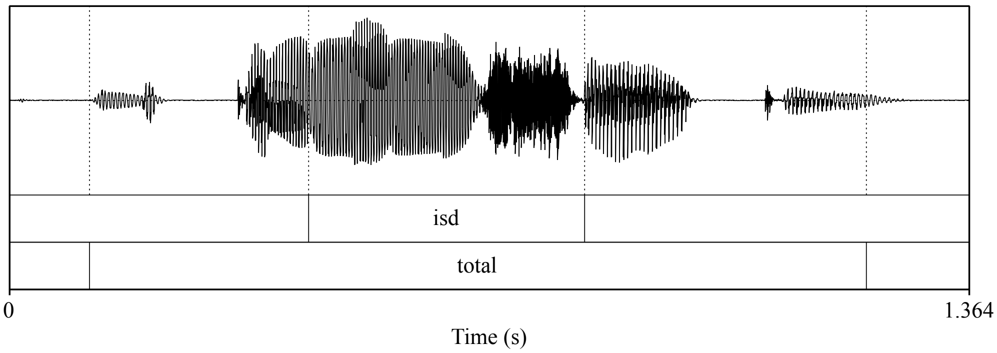
Gouskova & Roon (2013) conduct an experiment to investigate the factors that favor and disfavor secondary stress in subordinating compounds (compounds that contain a linker vowel, such as the [ə] in [bʲitòn-ə-mʲiʂálkə]). Relevant here is a potential factor involving rhythm: based on prior work by Avasenov (1964), Gouskova & Roon hypothesize that compounds should be more acceptable as the distance between the secondary and primary stresses grows. Thus, all else being equal, [bʲètən-ə-mʲiʂálkə] (with three syllables between the stresses) should be better-rated than [bʲitòn-ə-mʲiʂálkə] (with two), and [gòləv-ʌ-lómkə] 'puzzle' (with two syllables between the stresses) should be better-rated than [gʌlòv-ʌ-lómkə] (with only one).

In their experiment, participants were asked to rate the acceptability of each item, with a 1 corresponding to the highest rating (for the most natural items) and a 7 corresponding to the lowest. Gouskova & Roon show that as the distance between the stresses increases, the average rating goes down, meaning that speakers find compounds in which stresses are further apart more natural than compounds in which stresses are closer together. They show that this gradient definition of *CLASH fares better with respect to the data than does a more categorical definition (due to Yoo 1992), in which compounds whose stresses are separated by zero or one syllables are less acceptable than compounds whose stresses are separated by more. Concretely, they find that a statistical model assuming a gradient definition of *CLASH does better on measures of best fit than does a statistical model assuming a categorical definition.

Gouskova & Roon measure the distance between stresses by counting syllables and do not address the question of whether the appropriate measure could be a durationally-based measure that does not appeal to formal structure. It is thus an open question whether or not their results could be better modeled by appealing to a measure like normalized duration instead of the number of syllables between the stresses.

To address this question, I calculated a normalized duration for each of Gouskova & Roon's multi-stress compounds by dividing the interstress string by the total duration of the compound. This calculation follows the calculation done for the experiment reported in Section 4; an example showing the measured distances for [bʲitòn-ə-mʲiʂálkə] is in Figure 8.

Figure 8: Calculating normalized duration in [bʲitòn-ə-mʲiʂálkə] (isd = interstress duration)



I then replaced Gouskova & Roon's factor for "interstress distance" (number of syllables between the stresses) with "normalized duration", leaving everything else in the statistical model the same. In addition to the factor for duration, the model includes a four-level factor for stress type (whether the first member of the compound when in isolation has fixed stress, mobile stress, or no vowel) and an interaction between normalized duration and stress type. These additional factors are included in gray, as our interest here is only on the comparison between number of syllables and normalized duration. The results of this new model are provided in (30); see Gouskova & Roon's Table 4 (their p. 402) for the original. The two models are qualitatively similar, differing notably only in Stress type = vowelless; this effect was not significant in Gouskova & Roon's model.

(30) Model for stress clash in Russian compounds, using normalized duration

Factor	Coefficient	*t* value	Significant?
Intercept	3.95	–	–
Normalized duration	-12.43	-6.39	$p < .001$
Stress type = fixed	-1.35	-2.97	$p < .01$
Stress type = mobile	-0.58	-1.14	$p = .27$
Stress type = vowelless	-1.16	-2.31	$p < .05$
Normalized duration * fixed	6.77	1.92	$p = .06$
Normalized duration * mobile	2.48	0.91	$p = .38$
Normalized duration * vowelless	9.00	2.73	$p < .05$

To compare Gouskova & Roon's model (referencing syllables) with the model in (29) (referencing normalized duration), I obtained the AIC and BIC for both models. Both measures indicate that (29) is a better fit to the data than is Gouskova & Roon's (2013) model (AIC: 6782.45 vs. 6826.20; BIC: 6947.38 vs. 6991.13). The suggestion, then, is that speakers were more likely to be paying attention to the normalized duration between the primary and secondary stresses, rather than the number of syllables between them, when they were judging Russian compounds.

Another effect potentially providing evidence for phonetic rhythm comes from Finnish, where secondary stress is variable in five-syllable words (Karvonen 2008). In the general case, five-syllable words have a primary stress on the initial syllable and a secondary stress on the penult (e.g. kó.les.te.rò.li 'cholesterol', lék.si.ko.grà.fi 'lexicographer'). If the word-final syllable lacks an onset, however, secondary stress falls on the antepenultimate syllable instead (e.g. ér.go.nò.mi.a 'ergonomics', mé.lan.kò.li.a 'melancholy'). A possible interpretation of this effect is that stress cannot fall on the first vowel in a hiatus sequence (Karvonen 2008:312). However, it could also be possible to attribute this effect to a phonetically-defined version of NONFINALITY, which prohibits stress from coinciding with the word's right edge. Let us assume that there is a constraint, NONFINALITYPHON, which requires a certain amount of normalized duration between the rightmost stress and the stem's right edge. It is then possible to understand the Finnish effect in a different way: stress retracts in forms like ér.go.nò.mi.a because placing a second stress on the penult, as in ér.go.no.mì.a, would be too close to the right edge of the stem. Penultimate stress on a form like kó.les.te.rò.li is acceptable, however, because more material intervenes between the rightmost stress and the word's right edge.

These two effects – clash in Russian compounds and secondary stress in Finnish five-syllable words – are likely only two of a large number of effects that could be explained by reference to phonetic rhythmic constraints. Further work is necessary to locate and explicate them fully.

8. Conclusion

In this paper, I have argued from patterns of secondary stress in *-ization* that phonetic versions of *LAPSE and *CLASH need to be included in CON. As detailed in Section 7, these results add to a growing base of evidence that rhythmic constraints pay greater attention to duration than is commonly assumed. All of the work discussed here is thus consistent with a broader view in which stress placement is directly informed by phonetics (see also e.g. Lunden 2013, Ryan 2014).

The results discussed here also have broader implications for theories of stress. In order to accommodate the finding that phonetic versions of *LAPSE and *CLASH are a part of CON, the theory must recognize the existence of rhythmic constraints. This is not true of all theories of stress: Martínez-Paricio & Kager (2015), for example, propose a foot-based theory of stress that does not include rhythmic constraints as a part of CON. It is not clear how the effects documented here could be captured using only the constraints that they propose. This case study thus presents a strong argument for theories of stress that include rhythmic constraints and against those that don't.

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