REGULARLY INFLECTED FORMS CAN BE PROSODICALLY AMBIGUOUS IN ENGLISH[*]

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1. Introduction

In the literature on lexical access, there has been much debate on whether or not inflected forms are stored in the mental lexicon, and, if they are, which factors affect their storage. Two major approaches have been proposed to address this issue: one route models and dual route models. According to one route models, both regular and irregular forms are stored (e.g., Bybee, 1995), and their categorization, generation and retrieval are based on pattern association – that is, similarity to existing forms (Rumelhart & McClelland, 1986).

Dual route models, on the other hand, assume that inflected forms may be retrieved in different ways, depending on their type. In one such model, forms with irregular inflection are stored in the mental lexicon, while regularly inflected forms are decomposed during processing, since they are generated by rule (e.g., Pinker, 1991; Pinker & Prince, 1991; Prasada & Pinker, 1993; Marslen-Wilson & Tyler, 1998). Another dual route model, however, assumes that regularly inflected forms can be stored under certain conditions (e.g., Pinker & Ullman, 2002), which affects their processing. One such condition is frequency: regularly inflected forms that are very frequent can be stored in the lexicon as morphologically unanalysed chunks and are thus retrieved quickly, whereas those with lower frequency undergo morphological decomposition and are thus retrieved more slowly (e.g., Alegre & Gordon, 1999; Gordon & Alegre, 1999).

It has also been observed that the segmental profile of word-final clusters can affect the processing of inflectionally-complex words. In their examination of English past tense inflection, Post et al. (2008) compared participants' responses to regularly inflected forms, pseudo-inflected forms (i.e., forms with complex codas that fit the profile of inflected forms, such as voice-matched coronal + /t, d/; e.g., *fast*, *mild*), uninflected forms with coronal complex codas and voicing mismatch (e.g., *tent*, *belt*), as well as uninflected forms with a non-coronal final consonant in a complex coda (e.g., *lamp*, *milk*). They found that participants are slower with pseudo-inflected forms, like they are with regularly inflected forms, which is argued to indicate that lexical access is impacted by whether or not the item has the phonotactic profile of a possible inflected form.

In this paper, we build on Post et al.'s (2008) finding that phonotactics can influence processing. However, we situate our proposal more broadly: we hypothesize that the processing of regularly inflected forms is affected by their prosodic representation.

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Specifically, we hypothesize that both the phonotactic profile *and* the length profile of English regular past forms impact processing. In section 2, we discuss the prosodic representation of regular past forms in English. We show that the representation of these forms is potentially ambiguous, when they mirror the phonotactic and length profiles of monomorphemic words. Our predictions, which follow from this ambiguity, are provided in section 3. We then turn, in section 4, to describe the lexical decision task we employ that includes existing and novel regularly inflected past forms of different phonological shapes. In sections 5-6, we present our results, then discuss our findings in light of different proposals on lexical access and potential implications for storage.

2. Prosodic representations of monomorphemic and inflected forms

Regularly inflected words can violate the phonotactic and length constraints of mono-morphemic words (e.g., Goldsmith, 1990; Harris, 1994). The examples in (1) illustrate three phonotactic conditions holding of monomorphemic words that are not respected in inflected words: (1a) shows that word-final obstruent + stop clusters must be voiceless in monomorphemic strings, while voiced clusters are perfectly well-formed across an inflectional boundary; (1b) shows that nasal + stop clusters must be homorganic in monomorphemic words, while place sharing need not be respected across an inflectional boundary; and (1c) shows that fricative + fricative clusters are illicit in monomorphemic words, even though they are licit over an inflectional boundary.

(1) Phonotactic conditions on monomorphemic words:

	Monomorphemic:	Inflected:
a.	[lɑft] ‘loft’ vs. *[lɑvd]	[lʌv-d] ‘loved’
	[skrɪpt] ‘script’ vs. *[skrɪbd]	[rɪb-d] ‘ribbed’
b.	[sænd] ‘sand’ vs. *[sæmd]	[slæm-d] ‘slammed’
c.	*[CVfs]	[klɪf-s] ‘cliffs’

The examples in (2) demonstrate the length conditions that hold of monomorphemic words which, similar to what was observed in (1), are not respected in inflected words. (2a) shows that final rhymes in monomorphemic words are maximally three positions long (VVC or VCC). Inflected forms, though, permit an extra position (VVC-C or VCC-C); in other words, the attachment of inflection does not trigger any repair (e.g., cluster reduction) to accommodate the extra consonant. The examples in (2b) show that the condition in (2a) does not hold when the final cluster is coronal; in this situation, rhymes can contain four positions. The examples in the second column of (2b) show that the restriction on coronal place need not hold of inflected forms ([naif-t] is well-formed); indeed, parallel to (2a), an inflectional consonant can be added to a four-position rhyme (as in [boult-s]) without triggering any repair.[1]

[1] There are some exceptions to the length constraints identified in (2): a handful of words with non-coronal clusters permit four-position rhymes (e.g., [mæŋks] ‘Manx’, [skʌlpt] ‘sculpt’).

(2) Length conditions on monomorphemic words:

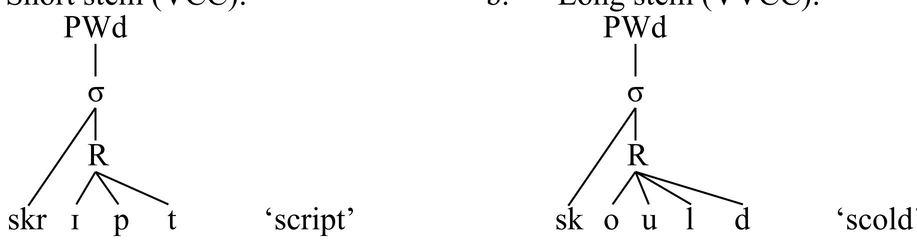
	Monomorphemic:	Inflected:
a.	Three-position rhymes:	
	[stri:k] ‘streak’, [strɪkt] ‘strict’ vs. *[stri:kt]	[stri:k-t] ‘streaked’
	[graip] ‘gripe’, [græsp] ‘grasp’ vs. *[graisp]	[graip-s] ‘gripes’

	Monomorphemic:	Inflected:
b.	Four-position rhymes:	
	[haist] ‘heist’ vs. *[haift]	[slais-t] ‘sliced’, [naif-t] ‘knifed’
	[boult] ‘bolt’ vs. *[boulk]	[boult-s] ‘bolts’

The patterns observed in (1) and (2) suggest that monomorphemic and regularly inflected words have different prosodic representations in English: monomorphemic words are simple prosodic words (PWds), as shown in (3), while regularly inflected words form recursive PWds, shown in (4) (Goad, White & Steele, 2003; Goad & White, 2006). The same representation holds for each type of word, regardless of the length of the stem-final syllable, ‘short’ (VCC for monomorphemic words; VC-C for inflected words) or ‘long’ (VVCC for monomorphemic words; VVC-C for inflected words).

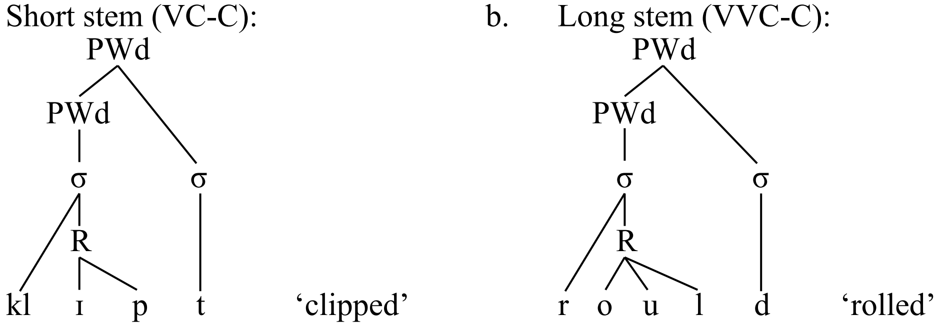
(3) Monomorphemic words:

a. Short stem (VCC): b. Long stem (VVCC):



(4) Regularly inflected words:

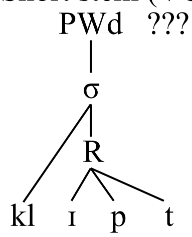
a. Short stem (VC-C): b. Long stem (VVC-C):



Although inflection is assumed to be organized in the same manner in all regularly inflected words, a comparison of the examples in (3) and (4) reveals that inflected words can sometimes respect the same phonotactic constraints as monomorphemic words. Short stem inflected words like [klɪpt] in (4a) have the same rhymal profile as short stem monomorphemic words like [skrɪpt] in (3a); and long stem inflected words like [rould] in (4b) have the same rhymal profile as long stem monomorphemic words like [skould] in (3b). This opens up the possibility that some inflected forms could be organized as simple PWds, henceforth ‘possible PWds’, as shown in (5).

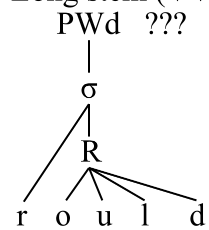
(5) Inflected words as possible PWds:

a. Short stem (VC-C):



‘clipped’

b. Long stem (VVC-C):



‘rolled’

Clearly, though, the parallel observed between (3) and (4) does not hold of all inflected words, as was illustrated earlier in (1) and (2). The forms in (6) show this more concretely: inflected words can be organized into groups depending on whether they respect or fail to respect the length and phonotactic constraints of monomorphemic words.

(6) Profile of regularly inflected words:

Short stem:	Possible PWd		Long stem:	Possible PWd	
	Phonotac	Length		Phonotac	Length
a. [klɪpt] ‘clipped’	✓	✓	b. [taipt] ‘typed’	✓	✗
c. [græbd] ‘grabbed’	✗	✓	d. [braibd] ‘bribed’	✗	✗
			e. [rould] ‘rolled’	✓	✓

A cluster like [pt] in (6a-b) is phonotactically well-formed at the end of a monomorphemic word, but this type of cluster can only follow a short vowel (e.g., [skrɪpt] in (3a)); four-position rhymes (akin to [taipt] in (6b)) are licit in monomorphemic words only when the final cluster is coronal (see (2b)). Hence, [klɪpt] is a possible PWd, but [taipt] is not. Turning to (6c-d), the same conclusion observed in (6a-b) holds for length, but the voiced counterpart of [pt], namely [bd], is not well-formed in a monomorphemic word (see (1a)). Hence, neither [græbd] nor [braibd] is a possible PWd. Consider finally (6e). Although words such as [rould] have four position rhymes, rhymes of this length are permitted in monomorphemic words when the final cluster is coronal (e.g., [skould] in (3b)). Hence, [rould] is a possible PWd.

In sum, if the simple PWd representation in (5) is potentially available for inflected forms, it should only be available for words of the types in (6a) and (6e), which respect both the phonotactic and length constraints of monomorphemic words.

3. Hypothesis and predictions

Our claim that a simple PWd representation will only be available for inflected forms that mirror the phonotactic and length constraints of monomorphemic words suggests that there are two possible representations for such inflected words: the simple PWd representation in (5) and the recursive structure required for all inflected forms in (4). In view of this, we return to our hypothesis, introduced earlier in section 1.

Most broadly construed, we hypothesized that the processing of regularly inflected words is affected by their prosodic representation. More specifically, we hypothesized that the phonotactic and length profiles of English regular past forms impact processing, because it is precisely these factors that determine whether one or more than one prosodic representation may be available to them. Following from this, we make two predictions that we experimentally probe with a lexical decision task:

(i) Inflected forms that are unambiguously recursive (6b-d) – based on their length and/or phonotactic profiles – are retrieved faster, as they are invariably decomposed prosodically;

(ii) Inflected forms whose profile could fit the simple PWd structure of monomorphemic words (6a,e) are retrieved more slowly, as two representations, one involving prosodic decomposition and one not, are available, thus leading to indeterminacy.

4. Methodology

To examine whether the prosodic representation of regularly inflected forms affects their processing, we conducted a lexical decision task with auditorily-presented stimuli. The task included 754 monosyllabic stimuli, of which 504 were target items and 250 were fillers. The target items were equally divided into real and nonce verbs, inflected and uninflected verbs, and verbs with long or short stems. Nonce verbs were generated by changing the onset of a real verb (e.g., *tave/taved* was generated from *save/saved*). Regarding the length of the stem, verbs with a long stem exhibited a diphthong or long vowel followed by a consonant (e.g., *roll/rolled*, *poke/poked*, *sneeze/sneezed*), while short stems had a short vowel followed by a consonant (e.g., *fill/filled*, *crack/cracked*, *buzz/buzzed*).

The inflected verbs were also coded as *possible* or *impossible PWds* (n = 90 and n = 162, respectively), as per the phonotactic and length constraints discussed above. For example, *rolled* and *cracked* are possible PWds based on both phonotactic and length constraints. Inflected verbs that are impossible PWds may violate phonotactic constraints (e.g., *buzzed*), length constraints (e.g., *poked*), or both types of constraints (e.g., *sneezed*). There were no items whose lexical status could be ambiguous (such as *build* and *billed*, or *find* and *fined*).

The task also included fillers, namely, non-verbs ending in /t, d/ (e.g., *flat*, *kind*) and verbs inflected for third person singular (e.g., *fills*, *cracks*, *jumps*). Half of the fillers were nonce words that were also generated by changing the onset of a real word. As will be mentioned below, uninflected items (i.e., half of the 504 target items) were also treated as fillers in the linear regressions, since these models focused on the factors that may be affecting participants' response times (RTs) to inflected items.

All of the real words (target items and fillers) were coded for word and rhyme frequency using the SUBTLEX Corpus (Brysbaert et al., 2012). Regarding rhyme frequency, we first determined the rhyme profile for each item based on the phonetic transcriptions available in the CMU Pronouncing Dictionary (Weide, 1993). Then, we used an R script (R Development Core Team, 2021) to obtain similar rhyme profiles for the items in the SUBTLEX Corpus and to obtain a frequency count for each rhyme profile.

The stimuli were recorded by a female native speaker of Canadian English with training in phonetics. The experiment was built using OpenSesame (Mathôt et al., 2012). There were two versions of the experiment. Each version included all of the fillers and half of the target items, for a total of 502 items per version. For any given target verb, if one version of the experiment contained an uninflected verb (e.g., *fill*), its inflected counterpart would appear only in the other version (e.g., *filled*), and vice-versa.

The experiment was completed by participants using a laptop computer. Stimuli were presented auditorily only, using AKG K 240 MK II semi-open studio headphones. At the beginning of the experiment, participants completed a practice block containing 20 items (which consisted of a random sample of the test items). The test items were then divided into three trial blocks, and participants could take five-minute breaks between blocks. Each stimulus was preceded by a beep and followed by 500ms of silence; participants' responses were also followed by another 500ms of silence before the next trial began. Participants were instructed to respond as quickly as possible using two laptop keys to record their answers, and their RTs were measured from when the audio stopped. The total duration of the experiment was approximately 45 minutes (including the breaks between blocks).

Participants were 18 adult native speakers of North American English. Although some participants reported having knowledge of other languages, none of them were simultaneous or early bilinguals. Exclusionary criteria included hearing impairment as well as having had chronic ear infections as children.

Participants' RTs and accuracy were analysed using hierarchical models with by-participant and by-item random intercepts in R, using the *lme4* package (Bates et al., 2015) – p values were obtained with the *lmerTest* package (Kuznetsova et al., 2014). Participants' accuracy was modelled with a logistic regression that included *inflection* (inflected vs. uninflected), *real* (real vs. nonce) and *length* (long vs. short) as main effects. Participants' RTs were modelled with two linear regressions, which included only inflected items. One linear regression included *real* and *length* as main effects, to examine the general trends present in the data. The other linear regression included *length* and *possible PWd* (yes vs. no) as main effects, as well as an interaction between these predictors. This model did not include nonce verbs, since only real items were coded for *possible PWd*. In the RT models, only the correct answers were included, and response times were log transformed. The effects of word frequency and rhyme frequency have also been examined but will not be discussed in this paper as they were not statistically significant (figures provided in the appendix).

For all models, RTs that were two standard deviations above or below a given participant's mean were excluded from the analysis. We do not expect that effects of prosodic representation will be reflected in participants' accuracy; rather, these effects will be observed in participants' RTs. Specifically, as mentioned in section 3, we predict that forms that are unambiguously recursive (see (6b-d)) – based on their length and/or phonotactic profile – will be retrieved faster, since they are invariably decomposed prosodically. On the other hand, inflected forms whose prosodic profile could fit the PWd structure of monomorphemic words (see (6a,e)) will be retrieved more slowly, since in this case the listener must arbitrate between two prosodic representations.

5. Results

We start by reporting on accuracy in the lexical decision task. Figure 1 shows participants' accuracy for inflected and uninflected nonce and real verbs, with long or short stems. The words in the bars exemplify the prosodic profiles under examination. As the bars in the plot suggest, participants are very accurate on all types of target items, even though they seem to be slightly more accurate with real verbs relative to nonce verbs. The statistical model confirms this result, with real items yielding a significantly higher accuracy than nonce items ($\hat{\beta}$ = 0.73, SE = 0.19, z = 3.73, p < 0.0001). The other predictors (*inflected* and *length*) were not statistically significant.

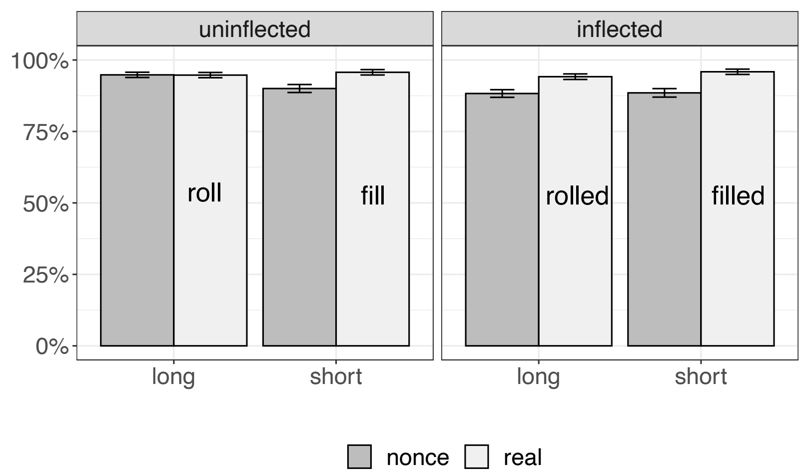


Figure 1. Participants' accuracy in the lexical decision task.

Regarding participants' RTs, we first examine the results for the overall trends in the data. The bars in Figure 2 suggest that participants are faster with real than nonce verbs, mirroring the accuracy results mentioned above, and that RTs are slightly slower with short stems. These results are confirmed by the statistical model (real vs. nonce: $\hat{\beta}$ = –0.16, SE = 0.02, t = –5.93, p < 0.0001; short stems: $\hat{\beta}$ = 0.08, SE = 0.02, t = 3.1, p = 0.002).

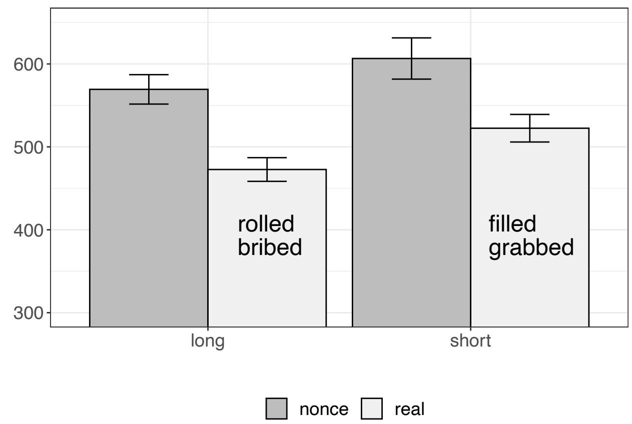


Figure 2. Overall RTs (inflected items only, correct answers only).

The results for real vs. nonce items are consistent with findings from previous lexical decision tasks (e.g., Vitevich & Luce, 1998). With respect to *length*, it should be noted that stem size alone does not determine prosodic structure, since both long and short stems may be compatible or incompatible with a simple PWd structure, as discussed in section 2. It is possible, though, that participants are overall faster with long stems because, as they are presented with the experimental items, they have more time to retrieve longer target items from their mental lexicon.

To examine the potential effect of prosodic representation on participants' responses, RTs for long and short stems must be analysed relative to whether they correspond to a possible PWd. This is shown in Figure 3. The bars in Figure 3 suggest no main effects of *length* and *possible PWd*, but instead an interaction between these predictors, since participants seem to be slower with inflected items that have short stems and correspond to possible PWds. The statistical model confirms these observations, as only the interaction between *length* and *possible PWd* is significant ($\hat{\beta} = 0.13$, SE = 0.06, $t = 2.1$, $p = 0.03$). This result is broadly in line with our prediction that, for inflected items that are prosodically ambiguous, responses should be slower – a word such as *filled* has the same length and phonotactic profile as a monomorphemic word such as *build*.

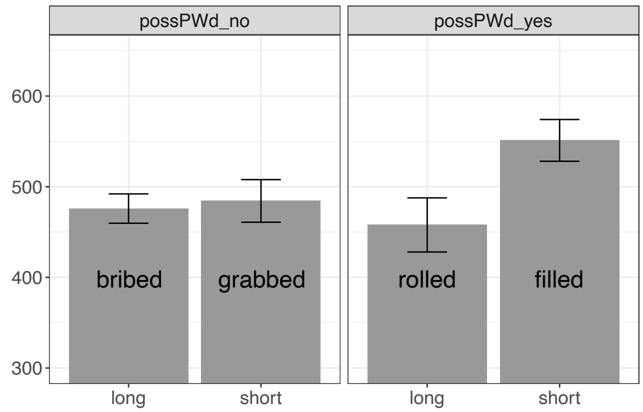


Figure 3. RTs for possible vs. impossible PWds in real inflected verbs (long vs. short stems, correct answers only).

6. Discussion and conclusion

Overall, the results of our experiment are consistent with our predictions: short inflected possible PWds are retrieved more slowly, which we have argued is due to listeners needing to arbitrate between two competing representations: the recursive structure in (4) and the simple PWd structure in (5). However, Figure 3 indicates that being a possible (simple) PWd only affects the processing of verbs with short stems: long inflected possible PWds are retrieved as quickly as long inflected impossible PWds. We conjecture that this is because long inflected forms are possible PWds under much more restricted conditions than are short inflected forms: in the former, the word-final cluster must be coronal, as was shown in (2b).

Our experiment was in part motivated by Post et al.'s (2008) finding that phonotactic profile influences processing. At the same time, our results do not align with those of Post et al. as the questions we have asked are somewhat different. Recall that in their paper, native speakers were found to be as slow processing pseudo-inflected forms (e.g., *mild*, *fast*) as they were processing inflected verbs. The authors concluded that speakers' lexical access of pseudo-inflected forms is conditioned by whether or not the item has the phonotactic profile of a possible inflected verb. However, Post et al. did not consider the inverse possibility, that pseudo-inflected forms could influence the processing of inflected verbs, which is what our results suggest. Accordingly, the authors also did not control for whether or not the phonotactic profiles of the inflected verbs they examined were compatible with the profiles of simple PWds (e.g., *filled* $[\text{fɪld}]_{\text{PWd}}$ vs. *loved* $*[\text{lʌvd}]_{\text{PWd}}$), nor did they control for the length of inflected verbs (e.g., *filled* vs. *rolled*).

Our results may appear to support dual route models of lexical access, where inflected forms are stored under some conditions. Specifically, our finding that the prosodic representation of regularly inflected (short) forms affects their processing could suggest that prosodic representation impacts storage: monomorphemic forms would be stored as simple

PWds (UR: [græb]$_{PWd}$ 'grab', [fɪl]$_{PWd}$ 'fill'), with the recursive structure present in inflected forms being built on the fly (computation: [[græb]$_{PWd}$ d]$_{PWd}$ 'grabbed', [[fɪl]$_{PWd}$ d]$_{PWd}$ 'filled'); crucially, inflected forms that conform to the phonotactic and length requirements of monomorphemic words would additionally be stored as simple PWds (UR: [fɪld]$_{PWd}$ 'filled'). The slower response time observed for inflected possible PWds would then be due to speakers needing to select between two competing prosodic representations.

We do not think that this position is tenable, for two reasons. One, it is not consistent with earlier literature which has proposed that some regularly inflected forms (such as highly frequent ones) are retrieved *more* quickly because they are stored in the lexicon as chunks as thus do not need to undergo morphological decomposition (e.g., Alegre & Gordon, 1999; Gordon & Alegre, 1999). We have found instead that the forms that would be stored are retrieved *less* quickly. Two, simple PWd structure is projected from syllables and feet; the latter levels of structure are standardly assumed not to be present underlyingly, since they are not contrastive within any language. If syllables and feet are built on the fly, it seems inconceivable that PWds (both simple and recursive) would not also be built on the fly.

Both of these observations indicate that another explanation must hold for our findings. We suggest that all of the inflected verbs, both possible and impossible PWds, are (a) stored in the same manner, (b) prosodically built on the fly, and (c) processed via decomposition.[2] The longer processing time associated with inflected possible PWds reflects indeterminacy. When listeners process a word, they must compute the appropriate prosodic structure. Since inflected possible PWds respect the phonotactic and length constraints of monomorphemic words, there is some delay in processing as listeners must arbitrate between competing prosodic representations, one compositional (the appropriate representation for inflected words) and one non-compositional (the appropriate representation for monomorphemic words), and then reject the latter.

In summary, our results support the hypothesis that the prosodic representation of regularly inflected words can affect their processing. This finding does not, however, lead to the conclusion that inflected forms (with certain phonotactic and length profiles) are stored in the mental lexicon.

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[2] Recall that in our experiment there were no effects of frequency, so we set aside the possibility that highly frequent words may be stored as chunks.

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Appendix

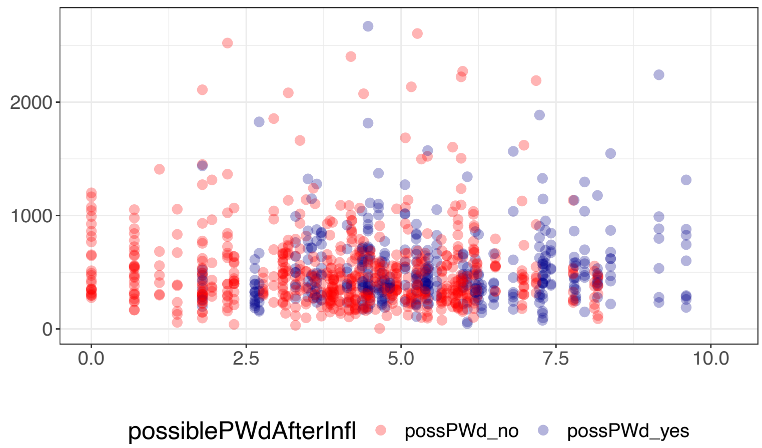

Figure 4. RTs (*y* axis) by word frequency (*x* axis).

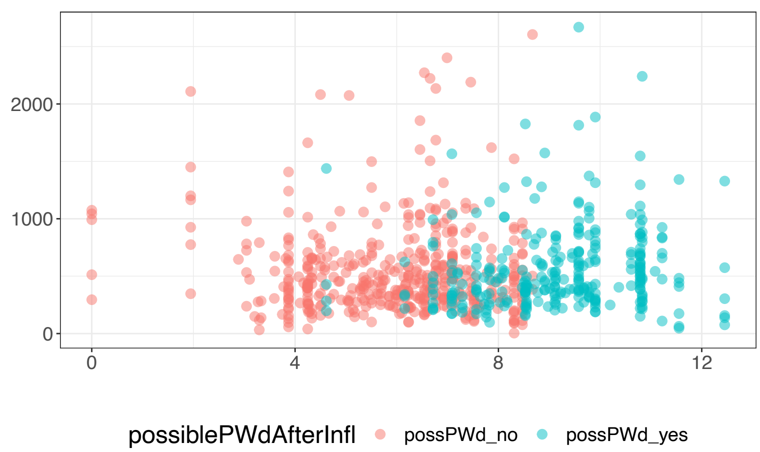

Figure 5. RTs (*y* axis) by rhyme frequency (*x* axis).