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Phonetic reduction can lead to lengthening, and enhancement can lead to shortening

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Abstract

Contextually probable, high-frequency, or easily accessible words tend to be phonetically reduced, a pattern usually attributed to faster lexical access. In principle, word forms that are frequent in their inflectional paradigms should also enjoy faster lexical access, leading again to phonetic reduction. Yet research has found evidence of both reduction and enhancement on paradigmatically probable inflectional affixes. The current corpus study uses pronunciation data from conversationally produced English verbs and nouns to test the predictions of two accounts. In an exemplar account, paradigmatically probable forms seem enhanced because their denser exemplar clouds resist influence from related word forms on the average production target. A second pressure reduces such forms because they are, after all, more easily accessed. Under this account, paradigmatically probable forms should have longer affixes but shorter stems. An alternative account proposes that paradigmatically probable forms are produced in such a way as to enhance not articulation, but *contrasts* between related word forms. This account predicts lengthening of suffixed forms, and shortening of unsuffixed forms.

The results of the corpus study support the second account, suggesting that characterizing pronunciation variation in terms of phonetic reduction and enhancement oversimplifies the relationship between lexical storage, retrieval, and articulation.
Index Terms: production, probability, pronunciation, corpus linguistics, English

1. Introduction

Phonetic reduction has long served as a tool to explore properties of lexical storage and retrieval. By almost all models of production, words that are more easily retrieved from memory can be more quickly encoded, thus facilitating articulation and increasing the speed of utterance. Factors which speed lexical retrieval should therefore also induce phonetic reduction. This prediction has been borne out in numerous studies, which show shortened duration, lower rates of epenthesis, higher rates of coronal stop flapping and deletion, and more centralized vowels in words that are contextually probable or have high lexical frequencies [1, 2, 3, 4]. In these respects, the relationship between speeded retrieval and reduced production is robust and frequently replicated.

A more fraught relationship concerns the link between phonetic reduction and *paradigmatic probability*, or the probability of using a particular inflectional form of a given lexeme. By the reasoning outlined above, the word form that is used most frequently in a given lexeme's paradigm should also be the word form that is easiest to retrieve, which means that word forms with high relative frequency in their inflectional paradigms should show more phonetic reduction. Yet empirical findings have not been as straightforward. On the one hand, corpus evidence has suggested that affixes on Dutch past participles are reduced when those participles are frequent with respect to their stems[5, 6]. Yet competing corpus research has also found evidence of what [7] calls the *Paradigmatic Signal Enhancement Hypothesis*, which states briefly that forms which are probable in their morphological paradigms are retrieved more confidently, leading to a more robust, enhanced articulation. Thus, in Dutch, interfixes in compounds are lengthened [7], and past tense verb suffixes are less likely to be deleted [8]. In English, plural suffixes on nouns that are used frequently in the plural compared to the singular are lengthened [9], and so are third-person singular suffixes on verbs [10]. Finally, recent work in Russian found evidence of both enhancement-like effects and reduction-like effects simultaneously influencing vowel quality in past-tense verbal suffixes [11].

1.1. Exemplar clouds and ease of retrieval

One possible explanation for these varying effects is an exemplar-theory account proposed in [11]. Briefly, this account suggests that the production target of a given word form is an averaged realization of all possible word forms within a lexeme, with non-target and infrequent forms exerting less of an influence. Pronunciation of frequent forms within the paradigm is therefore robust against the influence of infrequent forms, while pronunciation of infrequent forms is more malleable. In the case of a suffixed target (e.g., *runs*) and an unsuffixed non-target (e.g., *run*), the influence of the unsuffixed non-target will tend to shorten the duration of the suffix on the target. If the unsuffixed form has higher frequency relative to the suffixed form, the suffix will be shorter, and if the suffixed form has higher frequency, the suffix will be longer. This is the source of apparent enhancement of paradigmatically probable word forms.

At the same time, however, forms which are frequent in their inflectional paradigms are also retrieved and encoded more quickly, and hence available sooner for articulation. This would lead to phonetic reduction of paradigmatically probable forms. Thus, the apparently inconsistent effects of paradigmatic probability on affix pronunciation reflect the two competing pressures, one of which tends towards enhancement, and the other of which tends towards reduction.

Crucially, the above account applies only to affixes, because in a language with mostly concatenative morphology, it is only the affixes that differ across word forms within an inflectional paradigm, and thus it is only affixes whose realization can be influenced by non-target forms. Stems, which are shared between target and non-target forms, should be exempt from this enhancement effect. (More precisely, the effect of non-target stems on the realization of a target stem would be minimal,

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since target and non-target stems differ in pronunciation only inasmuch as the presence or absence of an affix changes the phonetic context of a stem, leaving coarticulatory traces.) Thus, the relationship between paradigmatic probability and the phonetic realization of the stem should be governed primarily by ease of retrieval: Wordforms that are frequent in their inflectional paradigms will be retrieved more easily, and regardless of the realization of the affixes, the stems should show phonetic reduction.

1.2. Contrast-dependent pronunciation variation

An alternative account for enhancement effects is the *Contrast-Dependent Pronunciation Variation* (CDPV) hypothesis proposed in [12]. By this account, word forms which are frequent in their inflectional paradigms are produced in such a way as to enhance the *contrasts* distinguishing them from competing members of the paradigm. In many ways, enhanced contrasts resemble general phonetic enhancement. With vowels, a front-back or high-low contrast can be enhanced through peripheralization, and the difference between a suffixed and unsuffixed form can be enhanced by lengthening the suffix on the suffixed form. Crucially, however, this enhancement of contrasts would go the other way on an unsuffixed form. To emphasize the absence of a suffix, the unsuffixed form should be shortened, more sharply distinguishing it from the longer, suffixed form.

Unlike the account based on exemplar clouds and ease of retrieval, CDPV predicts that suffixed forms should be lengthened as if they are frequent in their inflectional paradigms, while unsuffixed forms should be shortened.

1.3. The current study

The current study tests the predictions of these two accounts by analyzing spoken corpus data of English verbs and nouns, both in their bare form (e.g., *dog*, *think*) and in the form containing the *-s* suffix, which denotes plurality in nouns (*dogs*) and singular agreement in present-tense verbs (*thinks*). After controlling for other variables that affect duration, stem duration and suffix duration were analyzed as a function of paradigmatic probability. If the exemplar-based account from [11] holds, then probable suffixes should be longer, while *all* probable stems should be shorter. If CDPV holds, then probable suffixes *and* suffixed stems should be longer, while only probable unsuffixed stems should be shorter.

2. Method

2.1. Materials

All data came from the Buckeye Corpus of Conversational Speech [13]. This corpus consists of 40 1-hour informal conversations conducted between an interviewer, who was not recorded, and a speaker. The corpus was hand-annotated, such that all words are transcribed on the phone level, complete with starting and ending points for each phone. Word forms were also automatically tagged for part of speech. In the current study, all tokens containing the morphological tags VBP (verb, non-3rd sing. present), VBZ (verb, 3rd-sing. present), NN (noun, singular or mass), or NNS (noun, plural) were extracted by script. Suffixed forms (i.e., tokens with the tag VBZ or NNS) were kept only if their final phone was transcribed as [s] or [z]. Stem durations were calculated by summing the durations of every phone in the word for unsuffixed forms, and by summing the durations of every phone except the final [s] or [z] for suffixed forms.

The full inflectional paradigm was determined by matching each word form type with its lemma ID number in the CELEX lexical database [14]. This lemma ID number tags all inflectional forms of a given lexeme, distinguishing between parts of speech. Thus, for example, the lemma ID number 39588 picks out the singular noun *run* and its plural form *runs*, while the lemma ID number 39589 identifies the four distinct forms of the corresponding verb: *run, runs, running, ran*. Using this lemma ID number, the inflectional forms of all words extracted from the Buckeye corpus were identified. Frequency information for each of these forms was then taken from the part-of-speech SUBTLEX-US database [15]. The part-of-speech tagging in this database made it possible to ensure that the frequency of orthographically identical nouns and verbs, such as *run*, accurately represented the usage frequency of the intended part of speech. All types that did not exist in both CELEX and SUBTLEX-US were discarded, as were all suffixed tokens that did not end in [s] or [z]. The remaining 46299 forms – 26572 unsuffixed nouns, 9933 unsuffixed verbs, 7750 suffixed nouns, and 2044 suffixed verbs – were retained for analysis.

2.2. Analysis

Both stem and suffix duration were log-transformed and analyzed using mixed effects regression modeling, with random intercepts for speaker and lemma ID number. Since the complexity of the model precluded a maximal random effects structure [16], the final model included random slopes for paradigmatic probability and the factors that interacted with it, in order to minimize the risk of including speaker or item-specific random variation in the fixed effects estimate.

The models reported here were built in three stages. First, since duration can be affected by many variables unrelated to paradigmatic probability, a control model was built, to explain as much variability as possible with predictors already known to affect duration. Only predictors that significantly improved model fit by means of a log-likelihood ratio test were included in the model. Paradigmatic probability was added next, along with interactions with existing predictors. Improvement in model fit was again assessed by means of a log-likelihood ratio test. Finally, the random slopes for paradigmatic probability and its interactions were added. Observations from this full model with standardized residuals more than 3 standard deviations from 0 were trimmed, and the model was refit, yielding the models reported here.

2.2.1. Control variables

To account for as much variability in stem and suffix duration as possible, multiple control predictors were included in the model. **Previous mention** was a factor coding whether a given word form had previously been used in the discourse within the last 60 seconds. **Lexical frequency** was the log-transformed usage frequency of the word form matched by part of speech, as listed in the SUBTLEX-US database. **Speaking rate** was calculated in segments per second, based on the average duration of the 20 segments preceding the word. If there were not 20 segments between the stem and the beginning of the utterance, then speaking rate was calculated as the average duration of however many segments did intervene between the beginning of the utterance and the word onset. **Word length** was calculated as the number of letters in the word. **Adjacency to an utterance boundary or disfluency** was included as two factors, one indicating whether a word stem was preceded by an utterance

Table 1: *Summary of fixed effects for the model of the duration of the -s suffix. Rightmost two columns give the results of a log-likelihood ratio test of the full model against a simplified model that does not contain the predictor in that row.*

Predictor	β	SE(β)	t-value	χ^2	p
(Intercept)	-2.440	0.031	-79.07	–	–
length	-0.012	0.003	-4.04	16.3	$<$ **0.001**
rate	-0.011	0.001	-10.48	108.8	$<$ **0.001**
final voiceless	0.054	0.013	4.02	16.1	$<$ **0.001**
utterance final	0.602	0.009	67.12	3695.4	$<$ **0.001**
lgRatio	0.030	0.006	5.10	24.5	$<$ **0.001**

boundary or disfluency, while the other indicated whether it was followed by a boundary or disfluency. **Conditional probability** was represented by two variables: Forward conditional probability indicated the probability of using a particular wordform given the following word, while backward conditional probability indicated the probability of using a particular wordform given the preceding word. **Voicing of the final segment** can affect word duration, since vowels before voiced final segments tend to be longer than vowels before voiceless final segments [17]; therefore, a factor was created indicating whether the final segment was voiced in citation pronunciation (as listed in CELEX). **Part of speech** was a factor with the levels *noun* and *verb*. This factor was included because nouns and verbs tend to be used in distinct prosodic environments, which can have consequences for word duration.

2.2.2. Key variables

The key predictors of interest were the **paradigmatic probability**, calculated as the log-transformed frequency of the given wordform within its inflectional paradigm, and a factor indicated **the presence of a suffix**. The exemplar-bsed account predicts that there should be no interaction between the two predictors: as paradigmatic probability increases, all stems should be shortened regardless of whether there is a suffix or not, while the suffix should be lengthened. CDPV, by contrast, predicts that there should be an interaction: unsuffixed forms should be shorter as paradigmatic probability increases, while suffixed forms should be longer.

3. Results

3.1. Duration of the suffix

The model predicting the duration of the suffix analyzed only the 9794 observations that contained a suffixal [s] or [z]. Trimming outliers removed 84 observations (about 0.9% of the data), yielding the final model summarized in Table 1. Of all control predictors considered, duration was affected only by speaking rate, length, voicing of the final segment, and whether the word form was utterance final or not. Crucially, paradigmatic probability significantly improved model fit, such that suffixed forms with higher paradigmatic probability had longer suffixes ($\beta = 0.03, SE(\beta) = 0.006, t = 5.10$).

It is worth noting that paradigmatic probability did not improve model fit if the control model included part of speech as a predictor. This is because paradigmatic probability was highly correlated with part of speech, such that suffixed nouns had significantly higher paradigmatic probability than suffixed verbs ($t(2550) = 128.0, p < 0.001$). However, this relationship is not a confound, but rather a consequence of different sized inflectional paradigms between verbs and nouns. Since a noun lexeme has only singular and plural forms, its inflectional paradigm is smaller than a verb lexeme's, which contain between four and five forms, depending on whether the past tense and past participle are different. Therefore, fewer inflectional forms contribute to the total frequency of a noun's inflectional paradigm, increasing the relative frequency of a given form from that paradigm. In light of this fact, the final model of suffix duration excluded part of speech as a predictor, in order to let the effect of paradigmatic probability emerge.

3.2. Duration of the stem

The model predicting the duration of the stem analyzed the full data set of 46299 tokens, removing 554 observations, or about 1.2% of the data, and the model was refit, yielding the results reported in Table 2. Random slopes included the interaction of paradigmatic probability and the presence of a suffix by speaker (40 groups), and the presence of a suffix by lemma ID number (3213 groups).

Of key interest here were the three two-way interactions involving the presence of a suffix, part of speech, and paradigmatic probability. First, suffixed nouns were shorter than unsuffixed nouns ($\beta = -0.109, SE(\beta) = 0.009, t = -11.96$), but the pattern was reversed for verbs ($\beta = 0.281, SE(\beta) = 0.034, t = 8.09$), as illustrated in Figure 1. Additionally, unsuffixed nouns shortened as paradigmatic probability increased ($\beta = -0.029, SE(\beta) = 0.011, t = -2.59$), while suffixed nouns lengthened ($\beta = 0.092, SE(\beta) = 0.018, t = -5.23$), as illustrated in the left panels of Figure 2. A further interaction with part of speech and paradigmatic probability shows that the slope of the paradigmatic probability effect on verbs is smaller than on nouns ($\beta = -0.064, SE(\beta) = 0.015, t = -4.19$). The consequence of this interaction is that suffixed verbs do not show the lengthening effect of paradigmatic probability that nouns do, instead remaining relatively constant in duration across the whole paradigmatic probability range (top right panel

Table 2: *Summary of fixed effects for the model of the duration of the stem. Rightmost two columns give the results of a log-likelihood ratio test of the full model against a simplified model that does not contain the predictor in that row. Predictors that significantly improved model fit in interactions were not evaluated as simple effects.*

Predictor	β	SE(β)	t-value	χ^2	p
(Intercept)	-1.247	0.035	-35.23	–	–
length	0.138	0.002	88.00	5862.4	$<$**.001**
prevMention=yes	-0.040	0.003	-13.68	186.6	$<$**.001**
forCondProb	-0.156	0.011	-14.22	201.6	$<$**.001**
backCondProb	-0.065	0.000	-7.50	56.1	$<$**.001**
rate	-0.004	0.000	-10.73	114.9	$<$**.001**
lgFq	-0.037	0.003	-12.05	138.0	$<$**.001**
finalVoiced=no	-0.001	0.008	-0.16	–	–
uttInitial=yes	0.029	0.005	5.61	31.5	$<$**.001**
uttFinal=yes	0.250	0.003	80.86	6104.2	$<$**.001**
suffixed=yes	**-0.109**	**0.009**	**-11.96**	–	–
posverb	-0.534	0.017	-30.86	–	–
lgRatio	**-0.029**	**0.011**	**-2.59**	–	–
finalVoiced=no × suffixed=yes	-0.086	0.012	-7.27	51.0	$<$**.001**
suffixed=yes ×pos=verb	**0.281**	**0.035**	**8.09**	**63.7**	$<$**.001**
posverb×lgRatio	**-0.064**	**0.015**	**-4.19**	17.3	$<$**.001**
suffixedyes×lgRatio	**0.092**	**0.01**	**5.23**	**27.0**	$<$**.001**

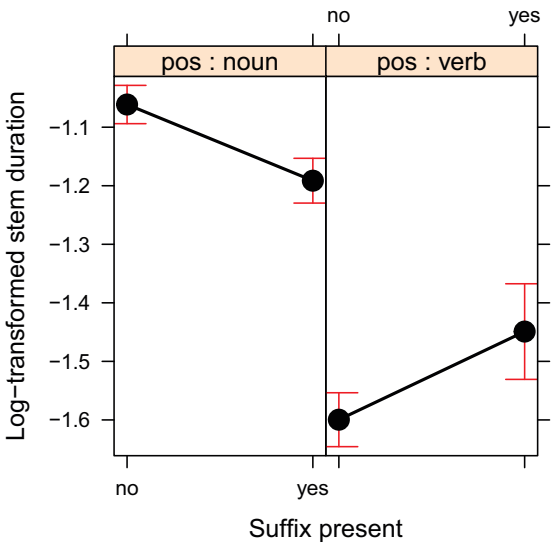

Figure 1: *Partial effects plot showing the interaction between part of speech and suffixation in the model of stem duration. Suffixed nouns are shorter than unsuffixed nouns, while the pattern is reversed for verbs.*

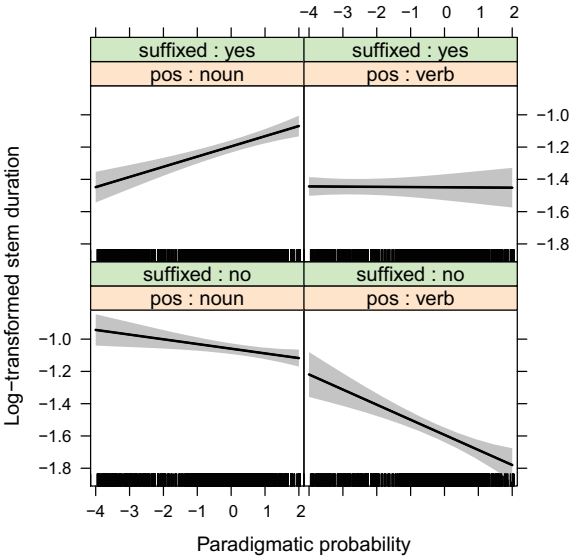

Figure 2: *Partial effects plot showing the two-way interactions of paradigmatic probability with part of speech and suffixation in the model of stem duration.*

of Figure 2), while unsuffixed verbs have an even more extreme shortening effect than nouns as paradigmatic probability (bottom right panel of Figure 2).

4. Discussion

The current project aimed to understand the role that paradigmatic probability has on lexical storage and retrieval and its consequences for pronunciation variation. Two accounts were evaluated. The first account, proposed in [11], suggests that multiple pressures are at play in the retrieval and articulation of complex words. The interaction of exemplar clouds in contributing toward the formation of a production target leads to lengthening of affixes when they are frequent within an inflectional paradigm, while a tendency towards reduction of easily retrieved material leads to shortening of the stems. The second account, proposed under the name of Contrast-Dependent Pronunciation Variation in [12], suggests that paradigmatically probable forms enjoy enhanced contrasts. This predicts lengthening of suffixed forms, especially the suffixes themselves, but shortening of unsuffixed forms — a pattern that enhances the durational contrast between them.

The corpus analysis presented here supports CDPV. Suffixed forms in both nouns and verbs were lengthened as paradigmatic probability increased, an effect observable both in the suffixes themselves and in the stems. By contrast, stem duration decreased as paradigmatic probability increased in both unsuffixed nouns and unsuffixed verbs. This enhancement of the durational difference between suffixed and unsuffixed forms with increasing paradigmatic probability is exactly the effect predicted by contrast-dependent pronunciation variation.

The results also revealed an interesting contrast in the effect of adding a suffix to nouns vs. verbs. Whereas the addition of a suffix on nouns led to shortening of a stem, the addition of a suffix on verbs lengthened it. This interaction could reflect the interplay of two different prosodic effects. The first is purely phonetic: Segment duration tends to decrease in longer words. Thus, a sequence like *sleep* is shorter in a word like *sleepy* than it is as a lone stem, and shorter still as part of the even longer word *sleepier* [18]. This phonetic effect would predict shortening of all stems when a suffix is added, simply because adding a suffix increases the length of the word. Counteracting this effect is an effect of pre-boundary lengthening. It has been observed for decades that identical segmental sequences tend to be longer before suffixes than before homophonous segments that are not suffixes. Thus, for example, the *uff* in *puff-ing* is longer than the *uff* in *puffin* [19, 20, 21].

Since verbs tend to have lower paradigmatic probability than nouns, they are more likely to be stored and retrieved as decomposed, parsed units, rather than retrieved as whole word forms [22]. This means that the morphological boundary between the stem and the suffix is stronger for verbs than for nouns. Thus, for noun stems adding an extra segment shortens the stem simply by virtue of the fact that the word is now longer, overcoming any lengthening that might have been induced by a morphological boundary between the stem and suffix. For verbs, on the other hand, the stronger morphological boundary leads to a stronger lengthening effect, counteracting and reversing any shortening that would be conditioned by the addition of more segments to the word.

5. Conclusion

The work presented here helps to clarify the role of paradigmatic probability in speech production, and also casts a cautionary light on the use of terms like *reduction* and *enhancement*. Although previous work has revealed that paradigmatically probable forms tend to be enhanced, enhanced articulation is not the same as enhanced contrasts. As these findings have shown, an enhanced contrast can lead to shortening, and a reduced contrast can lead to lengthening.

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