Arndt-Lappe, Sabine, Angelika Braun, Claudine Moulin & Esme Winter-Froemel. 2018. *Expanding the Lexicon: Linguistic Innovation, Morphological Productivity, and Ludicity* (The Dynamics of Wordplay v.5). Berlin/Boston: De Gruyter.

Ingo Plag and Sonia Ben Hedia

The phonetics of newly derived words: Testing the effect of morphological segmentability on affix duration

Abstract: Newly derived morphologically complex words have played a prominent role in research on morphological productivity and lexical innovation (e.g. Baayen 1989, 1996; Plag 1999; Mühleisen 2010). Most of the attention concerning the properties of such words has been devoted to their phonological, morphological, semantic and syntactic properties (see, for example, Bauer et al. 2013 for such analyses). This paper takes a look at the phonetic properties of affixed words, testing Hay's (2003) 'segmentability hypothesis', according to which newly derived words are expected to show less phonetic integration, hence less phonetic reduction, of the affix involved than established forms. This hypothesis is based on the idea that morphological segmentability negatively correlates with phonological integration. To date there is only one study that clearly confirmed the segmentability hypothesis (i.e. Hay 2007), while other studies have failed to replicate the effect (see Hanique and Ernestus 2012 for an overview). The present study investigates the issue with data from the Switchboard corpus for five affixes of English: *un-*, locative *in-*, negative *in-*, *dis-* and adverbial *-ly*. Using different measures of morphological segmentability, we demonstrate that the durations of the two prefixes *un-* and *dis-* (unlike the durations of *in-* and *-ly*) largely support the segmentability hypothesis. With *un-* and *dis-* prefixed words, prefixes that are more easily segmentable have longer durations. *

* The authors wish to thank the editors and the reviewers for their constructive feedback on an earlier version. We are also grateful for comments to the members of the DFG Research Unit FOR2373 and to the audiences at the Workshop on Expanding the Lexicon, Trier, 17–18 November 2016 and at the Old World Conference on Phonology, Düsseldorf, 20–22 February 2017. The usual disclaimers apply. This research was partially funded by the Deutsche Forschungsgemeinschaft (Research Unit FOR2373 'Spoken Morphology', Projects PL 151/7–1 and PL 151/8–1) and the Strategischer Forschungsfonds der Heinrich-Heine-Universität Düsseldorf, which we gratefully acknowledge.

https://doi.org/10.1515/9783110501933-095

1 Introduction

Neologisms and rare words have played a prominent role in research on morphological productivity (e.g. Baayen 1989, 1996; Plag 1999; Mühleisen 2010). Most of the attention concerning the properties of such lexical innovations has been devoted to their phonological, morphological, semantic and syntactic properties. For example, Plag (1999) provides a detailed analysis of the complex phonological alternations observable with 20th century neologisms in *-ize*, *-ify* and *-ate*. Work on morphological properties has been devoted, among other things, to possible and impossible affix combinations (e.g. Hay and Plag 2004; Plag and Baayen 2009). The semantics and syntax of newly derived words has been investigated, for instance, in Plag (1998), Barker (1998), Mühleisen (2010) and Schulte (2015). Bauer, Lieber, and Plag (2013) provide analyses at all four levels of description of a plethora of productive derivational processes in English.

Recently, another level of description has come under the radar of morphologists, phonetics (see, for example, Hanique and Ernestus 2012; Plag 2014 for overviews). There is some work that shows that, at least for some morphological categories, phonetic detail can tell us something about the morphological structure of a word. Morphologically complex words are often phonetically reduced (or otherwise phonetically variable) as compared to their citation forms (e.g. Pluymaekers, Ernestus, and Baayen 2005). And bases of complex words are phonetically different from the same form pronounced as a free morpheme outside the derived word in question (Kemps et al. 2005a, 2005b; Blazej and Cohen-Goldberg 2015). The extent and nature of such phonetic variability and its theoretical significance are still largely unclear, but it seems that phonetic detail may also be relevant for the question of how newly derived words and established words may differ.

Consider the word *government*. It is mostly pronounced [gʌvmənt] or [gʌvəmənt], not [gʌvərnmənt]. This phonological opacity goes together with semantic opacity: *government* does not primarily denote 'action of VERBing' (as is standardly the case with *-ment* derivatives), but rather denotes the people who govern, or, more generally, 'political authorities'. Other pertinent cases are *restless* and *exactly*, which are words that are often pronounced without a /t/. It has been suggested (e.g. by Hay 2003) that such cases of phonological opacity may not be idiosyncratic, but reflect different degrees of morphological segmentabilty, which in turn is influenced by the frequential properties of base and derivative (Hay 2001, 2003). *Government* is far more frequent than its base *govern* and is therefore less easily segmented than, for example, *enjoyment*, whose base is far more frequent than its derivative (see Plag 2003: Chapter 4 for an introduction to the notion of morphological segmentability). Similarly, *exactly* is far more frequent than its base and easily loses its /t/, while, for example, *abstractly* is much less frequent than its base and is unlikely to occur without its base-final /t/.

Phonetic variability may affect not only bases but also affixes. For example, Hay (2007) finds that the vowel of the prefix *un-* may be realized as a full vowel, as a schwa, or even be completely absent in running speech. The prefix may be realized with variable acoustic duration (measured in milliseconds) within and across speakers, and across different derivatives, even at the same speech rate. Hay (2001, 2003) demonstrates that this kind of phonetic variation is not random, and her results suggest that factors facilitating morphological decomposition (e.g. boundary-like phonotactics or low frequency of the derived form relative to the base) lead to phonetically longer pronunciations. In other words, according to Hay (2002, 2003), the degree of phonetic reduction is at least partially determined by the degree of morphological segmentability of the word in question. We will call this the 'segmentability hypothesis'.

Newly derived words are usually easily decomposable[1] since, crucially, this allows the hearer to access the constituent morphemes and compute the meaning of the word unknown to him / her on the basis of the individual morphemes (and / or the pertinent word-formation rule). It can thus be predicted that a newly derived word, or the affix that derives it, is phonetically less reduced than the same affix in an established form which is less easily decomposed. It is, however, very difficult to analyze the phonetic properties of newly derived words for two reasons. First, one does not know whether a given word that a given speaker uses is new to this speaker, even if it is new for other speakers. Second, in order to observe phonetic reduction, words should be observed in their natural context, i.e. in natural conversational speech (Tucker and Ernestus 2016). Unfortunately, existing speech corpora are usually rather small, and new coinages are rather rare events. Whether affixes in newly derived words are less reduced can, however, be indirectly tested by examining the effects of segmentability on all words. If there is a general effect of segmentability in the predicted direction, newly derived words will show the largest effects, as they are at the end of the segmentability scale.

The present paper tests the segmentability hypothesis with data from the Switchboard corpus (Godfrey and Holliman 1997) for five affixes of English: *un-*, negative *in-*, locative *in-*, *dis-* and adverbial *-ly*. Different measures of morpholog-

1 We use the term 'decomposable' when we refer to words, and the term 'segmentable' when we refer to affixes.

ical segmentability are investigated, and the results demonstrate that the durations of the prefixes *un-* and *dis-* largely support the segmentability hypothesis. With *un-* and *dis-* prefixed words, prefixes that are more easily segmentable have longer durations. This is indirect evidence that newly derived words, which necessarily rely on morphological decomposition, may have phonetic properties different from those of established forms. The suffixed words and the words derived with *in-*, as collected in our data set, do not show this effect, however, which raises interesting new research questions.

2 Phonetic implementation and morphological segmentability

As mentioned in the introduction, it has been claimed (e.g. by Hay 2003) that phonetic reduction in morphologically complex words reflects the degree of morphological segmentability. We have labeled this the 'segmentability hypothesis'. If true, this means that new morphologically derived words should show less phonetic reduction than existing words. This is due to the fact that neologisms derived by affixation need to be morphologically decomposed in order to allow the listener to come up with an interpretation of the new word, based on the meaning of the affix, the meaning of the base, and the context.

Hay (2007) presents evidence from English words derived with the prefix *un-* that such a reduction effect can indeed be found. In that study, relative frequency is used as a measure of segmentability. This measure is computed as the ratio of the frequency of the derivative and the frequency of the base. The rationale behind this ratio builds on dual route models of lexical storage and access, i.e. whole word vs. decomposed. Complex words with a high frequency of the derivatives vis-à-vis a low frequency of the base will have a very strong representation of the derived word in the mental lexicon, as against a rather weak representation of the base. This will lead to a whole-word bias in lexical processing. Conversely, having a derivative with low frequency and a corresponding base with a high frequency, this will support morphological decomposition since the base representation is strong, and the representation of the derivative is weak. In the extreme case of neologisms, there is no representation of the derived word yet, and decomposition is the only possibility.

Hay (2007) finds an effect of relative frequency, such that *un-* words that have a lower relative frequency (and thus are more easily segmented) show longer prefix durations. One problem with Hay's result is that many studies have failed to replicate the effect of relative frequency or of other measures of segmentability on durational properties of complex words. Apart from relative frequency, semantic and structural measures have been used to test the segmentability hypothesis. Semantic measures use some operationalized notion of semantic transparency. The more semantically transparent a derivative, the more easily it can be segmented. Measures of semantic transparency are standardly gathered through rating experiments with ordinary language users, or, alternatively, through ratings by trained experts. Structural measures make recourse to structural distinctions based on boundary strength (e.g. phrase-boundary vs. word boundary vs. affix boundary), types of bases (e.g. phrases vs. words vs. roots), or prosodic domains (phrase boundary vs. word boundary vs. foot boundary vs. syllable boundary).

Research on the acoustic correlates of segmentability is still scarce, and is not exclusively limited to features that encode reduction. Table 1 summarizes various pertinent studies and their results, ordered by the columns ‘Effect found’ and ‘Predictor’.

Tab. 1: Overview of pertinent studies

Author	Language	Affix	Dependent variable	Predictor	Effect found
Sproat and Fujimura 1993; Lee-Kim, Davidson, and Hwang 2013	English	coda /l/	velarization	boundary strength	yes
Ben Hedia and Plag 2017	English	*un-*, negative *in-*, locative *in-*, negative	duration of prefixal nasal	boundary strength	yes
Smith, Baker, and Hawkins 2012	English	*dis-*, *mis-*	duration	boundary strength	yes
Plag, Homann, and Kunter 2017	English	*-s*	duration	boundary strength	yes
Hay 2003	English	*-ly*	duration	relative frequency	yes
Hay 2007	English	*un-*	duration	relative frequency	yes
Pluymakers et al. 2011	Dutch	*-igheid*	duration	boundary strength	no

Author	**Language**	**Affix**	**Dependent variable**	**Predictor**	**Effect found**
Bürki et al. 2011	French	*re-*	presence / absence of schwa	boundary strength ratings	no
Schuppler et al. 2013	Dutch	*-t*	presence / absence	relative frequency	no
Pluymaekers, Ernestus, and Baayen 2005	Dutch	*ge-*, *ont-*, *ver-*, *-lijk*	duration	relative frequency	no
Smith, Baker, and Hawkins 2012	English	*dis-*, *mis-*	duration	relative frequency	no
Plag, Homann, and Kunter 2017	English	*-s*	duration	relative frequency	no

Only four languages have been investigated so far, Dutch, English, French and German. Only two studies, both based on English, have found evidence for an effect of relative frequency. Four other studies have failed to find this effect. A number of studies have looked at effects of structurally-based boundary strength, sometimes finding effects, sometimes not finding them. In general, it seems impossible at this stage to say which factor may be responsible for the presence or absence of the expected effect in a given study.

It should also be noted that the studies listed in Table 1 approached the problem from two different angles, word-based or category-based. While relative frequency is a word-based measure, i.e. a measure that pertains to a particular word, measures of boundary strength are often averaged over sets of derivatives to compare affixes. For example, Smith, Baker, and Hawkins (2012) investigated whether pseudo-prefixes (which have a weaker boundary) show more reduction than real prefixes. Similarly, Plag, Homann, and Kunter (2017) found durational differences between different types of final /s/ and /z/ in English (non-morphemic vs. suffix vs. clitic). Ben Hedia and Plag (2017) compared the duration of the prefixal nasal across three prefixes that vary in their average boundary strength (*un-* having a stronger boundary than negative *in-*, which in turn has a stronger boundary than locative *in-*). Since the present paper focuses on properties of individual words we will only use word-based measures of segmentability.

In order to shed more light on the potential effects of segmentability on the phonetic properties of derived words, the present study will investigate five affixes of English, *un-*, negative *in-*, locative *in-*, *dis-* and adverbial *-ly*. The negative prefix *un-* is highly productive and creates highly transparent derivatives, usually on the basis of words. Both *in-* prefixes have different allomorphs that show place assimilation with the base-initial consonant. The negative prefix *in-* (as in *impossible*) is a bit less productive, has some less transparent derivatives (e.g. *insane*) and is often based on bound roots. The locative prefix *in-* (as in *implant*, *immigration*) has many opaque derivatives and is often attached to bound roots. Based on frequential and semantic measures, Ben Hedia and Plag (2017) show that of the three prefixes, *un-* is the most easily segmentable, followed by negative *in-*, followed by locative *in-*. The negative prefix *dis-* is highly productive, but also has some less transparent derivatives in its category. Finally, the suffix *-ly* derives adverbs from adjectives. Its status as inflectional or derivational is debated (see Plag 2003: 195–196; Payne, Huddleston, and Pullum 2010; Giegerich 2012), but everybody agrees that the suffix is fully productive and, apart from very few exceptions (such as *hardly*), there are only fully transparent formations.

3 Methodology

3.1 Data

In order to investigate the kinds of questions raised in the previous sections, it is necessary to investigate natural conversations because it is in this type of speech that reduction processes are most likely to occur (see Tucker and Ernestus 2016 for discussion). All words for this study were taken from the Switchboard Corpus (Godfrey and Holliman 1997). This is a collection of about 2400 two-sided phone conversations among North American speakers of English, with over 3 million word tokens. The data were originally extracted from the corpus for a study of gemination effects of consonants across the morphemic boundary, e.g. with words such as *un-necessary*, *im-mobile*, *im-migrate, dis-similar, oral-ly* (Ben Hedia in preparation; Ben Hedia and Plag 2017). The data set can, however, also be fruitfully employed for the purposes of this study by using a different acoustic measurement, i.e. affix duration instead of duration of the consonant at the morphemic boundary.

We investigate four different subsets of data. One subset contains *un*-prefixed words, one *dis*-prefixed words, one *in*-prefixed words and one *-ly*-suffixed words. The *in*-data set is composed of *in*-prefixed words with allomorph /ɪm/. This was necessary for the purposes of the gemination study because words with the allomorph /ɪn/ and a following base-initial /n/ are extremely rare.

The morphological status of a word was defined by using established criteria (cf. e.g. Plag 1999: Chapter 5; Bauer, Lieber, and Plag 2013: Chapter 3.2.2; Schulte

2015: Chapter 6). All words that show the affixational meaning and whose base is attested outside the derivative with a similar meaning, counted as morphologically complex. It did not matter whether the base occurs as a free morpheme (e.g. *natural* in *unnatural*) or as a bound morpheme (e.g. *-plicit* in *implicit* and *explicit*).

Each data set includes up to 160 tokens. We included as many different types as possible for each affix with the restriction that for each affix a sufficient number of words with a singleton (e.g. *unfit*), as well as with a double consonant at the morphological boundary had to be included (e.g. *unnatural*). Since morphological geminates are extremely rare with some affixes (e.g. only six different types for the prefix *un-* in the whole corpus), some types were included several times in the data set. Table 2 shows the number of different types and tokens for each data set.

Tab. 2: Overview of the data

Affixes	**Types**	**Tokens**
un-	101	158
in-	83	156
negative *in-*	29	86
locative *in-*	54	70
dis-	58	108
-ly	146	150
Total	398	596

3.2 Acoustic segmentation

After all sound files were extracted from the corpus, text grids were generated with a Python script for all sound files. The segmentation and transcription of the data was carried out manually using the software Praat (Boersma and Weenink 2014). We annotated the word and the affix in question, as well as the segments of the syllable adjacent to the affix. Double consonants straddling the morphemic boundary were segmented as one segment, since in most cases no boundary between the two consonants was discernible.

The criteria for the segmentation were developed by consulting the relevant phonetic literature (cf. Ladefoged and Maddieson 1996; Johnson 1997; Ladefoged

2003; Machač and Skarnitzl 2009; Ladefoged and Johnson 2011) and were optimized during the segmentation process. The beginning of the prefixed word was marked at the point where the waveform as well as the spectrogram visibly displayed the features of the word initial segment, in the case of *un-* and *in-* a vowel, in the case of *dis-* a stop. Vowels are characterized by a high amplitude, as well as a clear and distinct formant structure. The occlusion of /d/ marked the beginning of *dis*-prefixed words. The end of *-ly*-suffixed words was marked where the clear formant structure of the word-final vowel diminished and the amplitude of the waveform decreased. In the case of a following vowel, the boundary between the two vowels was set where the formant structure visibly changed.

To set the boundary between affix and base, the spectral and amplitudinal features of nasals (for *un-* and *in-*), fricatives (for *dis-*) and laterals (for *–ly*) were considered. Nasals have a regular waveform which has a lower amplitude than the waveform of vowels. Formants of nasals are quite low and faint in comparison to those of vowels. Boundaries between the nasal and a following vowel were marked at the point where the amplitude increases in the waveform and the formants become clearly visible. Approximants following the nasal were identified in a similar way as following vowels, since, like vowels, they have a higher amplitude than nasals, as well as more acoustic energy. If a stop followed the nasal, the boundary was marked at the beginning of the occlusion, which was identified by the abrupt decrease of the waveform and the sudden diminishment of the formants. In the case of a following fricative, the boundary was set where the waveform became visibly irregular and the energy was concentrated in the upper part of the spectrogram with no distinct formants visible.

Fricatives are characterized by an irregular waveform, which is very easy to distinguish from the regular waveform of vowels. Furthermore, for fricatives, there is energy throughout the whole spectrogram and no separate formant bands are visible. Most energy is visible in the upper part of the spectrogram. This is even more pronounced for voiceless fricatives, i.e. all of the *dis*-prefixed words in the data set. The boundary between /s/ and the following vowel was set where the waveform became regular and a distinct formant structure became visible. In the case of a following approximant, the same criteria were followed. If a stop followed the fricative, the boundary was marked at the beginning of the occlusion. There were no fricatives immediately following the prefixal /s/ in the datasets.

Laterals are very similar to vowels regarding their acoustical properties. Thus, it is quite challenging to set a boundary between vowels and laterals. However, there are some aspects in which /l/ can be distinguished from vowels. There is less amplitude in the waveforms of laterals than in those of vowels. Furthermore, their formant structure, in contrast to that of vowels, is constant. Due to less energy in the speech signal, the formants of /l/ are in general fainter. For intervocalic /l/ a visible decrease in the waveform, as well as the change in formant structure was used to mark the beginning of /l/. All boundaries were set at the nearest zero crossing of the waveform.

The reliability of the segmentation criteria was verified by trial segmentations in which it was ensured that all annotators placed all boundaries with only small variations. For the final measurement, each annotator worked on a disjunct set of items. After the segmentation process was completed, a script was used to measure and extract word duration, the number of segments in the word, the duration of the nasal in question, and the duration of its preceding and following segments in milliseconds.

3.3 Predictor variables

The duration of segments in natural speech is subject to a variety of different influences, and in order to address our research question these influences need to be controlled for. This can be done by coding the pertinent variables and using them as independent variables in a multiple regression model. We can distinguish variables of interest and noise variables. In our case, the variables of interest are the morphological segmentability measures. In addition to the variables of interest there are of course many other factors that might influence the duration of segments in speech production, such as speech rate or the following segment. In the following, we will describe all variables which were included in the models. First the variables of interest, i.e. the segmentability measures, will be explained. Then we will turn to the noise variables.

Segmentability. We used four different measures of segmentability: two measures of semantic transparency, relative frequency and type of base. We will discuss each in turn.

Semantic transparency has been used extensively in psycholinguistic research to investigate the question of whether words are processed as wholes or whether they are decomposed into their constituent morphemes (see, for example, Marslen-Wilson 2009 for an overview). These studies have shown that transparent words are more easily decomposed than non-transparent words. We created two variables to test semantic transparency. The first one is SemanticTransparencyBinary, in which we coded for each word whether its meaning was transparent or opaque. If the meaning of the derivative was fully compositional, it was categorized as transparent. We checked the meaning of the derivatives and their bases in the online version of the *Oxford English Dictionary* (OED 2013). We coded those words as fully compositional in which the meaning of the derived word is straightforwardly computed by combining the meaning of the affix with the meaning of the base. Examples of transparent words are *unnatural* and *impossible*, whose meanings can be paraphrased as combining the prefixal meaning 'not' with the meaning of the base. Words that did not meet this strict criterion were categorized as opaque, as, for example, *impression* or *imposed*.

The second variable we used to measure semantic transparency is SEMANTICTRANSPARENCYRATING. We conducted a survey in which all the complex words included in this study were rated for their decomposability. In an online experiment using LimeSurvey (https://www.limesurvey.org/) native speakers of American English were asked how easy it is to decompose a given word into two meaningful parts on a scale from 1 ("very easy to decompose") to 4 ("very difficult to decompose"). The prefixes *un-* and *in-* were rated in one rating survey, for the affixes *dis-* and *-ly* separate rating surveys were conducted. A total of 110 participants between the ages of 16 and 63 rated the items. The reliability of the judgements was checked by a thorough inspection of the data (including the calculation of item-total correlations), as well as by computing Cronbach's α (Cronbach 1951) for each rating. After all ratings turned out to be reliable ($\alpha \geq 0.97$), we coded the median of the ratings for each word (i.e. type) in the variable SEMANTICTRANSPARENCYRATING.

Another measure of decomposability is probabilistic in nature: relative frequency (Hay 2002, 2003). Relative frequency is defined as the ratio of the frequency of a derived word to the frequency of its base. The more frequent a derivative is in comparison to its base, the higher its relative frequency and the less decomposable it is. We computed the variable RELATIVEFREQUENCY by dividing a word's lemma frequency by its base lemma frequency.[2] Frequencies were extracted from the DVD version of the Corpus of Contemporary American English (COCA, Davies 2008), using the query tool Coquery (Kunter 2016). We consider COCA an appropriate source for the frequency counts because the data in this corpus come from the same variety of English as the speech data in the Switchboard Corpus, i.e. North American English. Following standard procedures relative frequency was log-transformed to reduce the potentially harmful effect of skewed distributions in linear regression models.

The fourth measure of segmentability is structural in nature and concerns the distinction between bound roots and words as bases. Derivatives with words as

---

2 Bound roots do not occur outside of the words whose base they are. In accordance with common practice, bound roots were therefore assigned the lowest possible frequency, i.e. 1.

bases can be assumed to be more easily decomposed than words that have a bound root as their base. This distinction was coded for each derivative in the variable TypeOfBase.

Affix. We coded the factor Affix, using the five levels `un`, `inNeg`, `inLoc`, `dis` and `ly`. Since we devised separate analyses for each affix, this factor plays a role only in the analysis of *in-*.

Affix-adjacent segment. Phonetic studies have shown that the duration of consonants depends heavily on the following segment. For nasals, following vowels lead to shorter durations, while following consonants increase duration. For voiceless fricatives, a following vowel leads to longer durations than a following consonant (Umeda 1977: 854). For the three prefixes, it is therefore important to account for the difference between a following vowel and a following consonant. We coded the variable FollowingSegment with the two levels `consonant` and `vowel` to account for possible effects of the following segment on the duration of the prefix.

Umeda (1977) also showed that the preceding segment influences the duration of consonants. For laterals, a preceding consonant leads to shortening (Umeda 1977: 851). This is of relevance for the suffix *-ly*, which can be preceded by a consonant or a vowel. Therefore, we coded the variable precedingSegment with the two levels `consonant` and `vowel` in the *-ly*-dataset.

Number of consonants. As shown in a previous study on a subset of this data (Ben Hedia and Plag 2017), morphological geminates display longer durations than singletons, i.e. for *un-* and *in-*prefixed words a double nasal (e.g. /nn/ in *unnatural*) is longer than a singleton (/n/ in *uneasy*). In such cases it is impossible to tell where the morphological boundary would be located inside the stretch of two adjacent identical consonants straddling that boundary. Hence, in order to account for the influence of the number of cross-boundary consonants in the word, we simply coded the variable NumberOfConsonants with the two levels `single` and `double`. Words such as *un-necessary*, *im-mobile*, *im-migrate, dis-similar, oral-ly* are coded with the value `double`, words such as *im-possible* or *sad-ly* are coded as `single`.

Speech rate. We coded the variable SpeechRate for each word by dividing the number of segments included in the word by the total word duration in seconds. It is expected that the more segments are produced per second, i.e. the higher the speech rate, the shorter the duration of the affix will be.

Stress.[3] Stressed syllables tend to have a longer duration than unstressed syllables (e.g. Fry 1955, 1958; Lieberman 1960; Beckman 1986; Harrington et al. 1998; see also Laver 1994 for an overview). Thus, if an affix bears stress, it might be longer. Coding affix stress is however quite challenging. While the suffix *-ly* is never stressed, the presence or absence of stress is a potential problem with the prefixes investigated in this paper. This is because the stress status of prefixes is difficult to determine and not well researched. While it seems uncontroversial that prefixes bear (secondary) stress when followed by an unstressed syllable, it is often unclear whether they are stressed or unstressed when followed by a stressed syllable. In pronunciation dictionaries, such as Wells (2008), the prefix in those cases is sometimes stressed, sometimes unstressed and sometimes variably stressed. However, as shown by Hanote et al. (2010: 2ff.) for the prefix *un-*, the stress assignment in Wells (2008) does not follow any systematic pattern. Furthermore, in conversational speech (as found in our data), additional contextual factors might influence the stress status of the prefixes (cf. Videau and Hanote 2015). The matter is further complicated by the difficulty in determining the relative prominence relation between the prefix and a following stressed syllable, i.e. coding prefix stress is quite challenging. Because of the difficulty coding prefix stress (unsystematic annotation in dictionaries, potential contextual influences, difficulty of determining prefixal stress based on acoustic properties) we did not code prefix stress in one of our variables. Instead we coded base-initial stress. As explained above, only when the base-initial syllable is stressed can a prefix be unstressed. If the base-initial syllable is unstressed, the prefix must be stressed. Therefore, we can at least partially account for prefixal stress by coding for the stress status of the base-initial syllable of a prefixed word. Coding for base-initial stress is also relevant in view of Umeda's (1977) finding that consonants before unstressed vowels are shorter, i.e. there might be an independent effect of the presence or absence of stress in the base-initial syllable on prefix duration. A possible explanation for this effect is that the lengthening of the adjacent stressed syllable spills over to the prefix. The variable StressPattern was therefore coded with regard to the base-initial syllable, with the levels `beforeStressed` and `beforeUnstressed`.

Syllabicity. In words ending in the suffix *-ly*, the lateral is sometimes syllabic. This occurs quite often when the suffix *-al* precedes *-ly* (e.g. in words like *educationally* or *mentally*). The schwa preceding /l/ is deleted, and /l/ becomes

3 Note that another potentially confounding factor for the coding of stress is that in English primary stress may shift to the prefix for emphatic purposes. None of the prefixes in our data, however, bears such primary stress.

syllabic. It is claimed in the literature that syllabic consonants are longer than non-syllabic consonants (see, e.g. Jones 1959: 136; Price 1981; Clark and Yallop 1995: 67). To consider possible effects of syllabicity on duration, we coded the variable SYLLABICITY for the suffix *-ly*, with the two levels `yes` and `no`.

Utterance Position. Words uttered at the end of an utterance or phrase have been shown to be pronounced with a longer duration than words in mid-positions (e.g. Oller 1973; Berkovits 1993). Some studies found the lengthening effect to be restricted to the final syllable of a word. For example, utterance-final position of *un*-prefixed words did not have a lengthening effect on prefixal /n/ (Hay 2007). But there is also evidence that segments occurring in the first syllable of a word participate in phrase- or utterance-final lengthening processes (Oller 1973). We therefore included the variable POSITION in which we coded whether the item was utterance final, followed by a pause or produced in mid position, i.e. immediately followed by the next word.

Word Form Frequency. Frequency has been shown to affect the duration of a word. More frequent words tend to have shorter durations (see, e.g. Aylett and Turk 2004; Gahl 2008). One would therefore expect shorter affix durations with more frequent words. To account for this effect we included Word Form Frequency (taken from COCA) as a covariate (WORDFORMFREQUENCY). We log-transformed this variable before it entered the models.

3.4 Statistical analysis

To see whether the segmentability affects the duration of the affixes in our data set we fitted linear regression models to each of the data sets. In all models the absolute duration of the affix in seconds was used as the dependent variable.

Given that many factors may play a role in the production of sounds, a multivariate method of analysis is called for. We opted for multiple regression because it allows the researcher to look at the effect of one predictor in the presence of other, potentially intervening, predictors. The use of mixed effects models was precluded by the data's unnestedness. The vast majority of items is produced by a different speaker and many items occur only once in the corpus, so that it did not make sense to use these variables as random effects.

As a general strategy, in order to avoid overfitting, we started the analyses of the different data sets with a baseline model that had only a rather small number of pertinent predictors: SPEECHRATE and NUMBEROFCONSONANTS. Both of these predictors can be expected to have a straightforward effect on the duration of the affix in question and can serve as a reality check on our data. We then added additional predictors individually and in different orders. In total, there were never more than three predictors that survived in our final models. In general, if a predictor showed a p-value lower than or equal to 0.05, and if the Akaike Information Criterion (AIC) of the model including the predictor was lower than when the predictor was not included, the predictor was kept in the model. Non-significant predictors were eliminated. The particulars of the modeling procedure specific to each affix are described in the pertinent result section below.

There are a number of measurements that we would want to use in our analysis that are correlated with each other. This can lead to serious problems in regression models ('multicollinearity', e.g. Baayen 2008: Chapter 6). This holds in particular for the four measures of segmentability which tend to go together. For example, words with a higher relative frequency (or those with bound roots) also tend to be semantically less transparent. One strategy to deal with collinearity is to include only one of the correlating variables. This is a conservative and safe strategy, which may, however, decrease the power of the model. If collinearity only affects noise variables, another option is to keep the correlating variables in the model but not interpret their individual contribution to the model (cf. Wurm and Fisicaro 2014). Another strategy to address collinearity issues is principal component regression (see, e.g., Baayen 2008: Chapter 5; Venables and Ripley 2011). This method will be used in the analysis of the prefix *dis*-.

For the statistical analyses presented in this paper, we used R (R Development Core Team 2014). The regression analyses were done with the `MASS` package (Venables and Ripley 2011). The plots of the models were generated with the `visreg` package (Breheny and Burchett 2015). For a plot showing the effect of a variable, all other variables are held constant at the median (for numeric variables) or at the most common category (for factors).

4 Results

4.1 The prefix *un*-

This prefix is characterized by the fact that its derivatives in general, and in our data set, are semantically highly transparent and that its bases are words, not bound roots. Of the four segmentability measurements, only RelativeFrequency was distributed with enough variation to be used as a predictor. To the baseline model we added the following predictors according to the procedure described in section 3.4: RelativeFrequency, WordFormFrequency, StressPattern, Position, and FollowingSegment.

In the final model only three predictors survive as significant, RELATIVEFREQUENCY, SPEECHRATE and NUMBEROFCONSONANTS. The regression model is documented in Table 3.

Tab. 3: Final regression model for *un-*; Adjusted R-squared = 0.45

	Estimate	Std.Error	t-value	Pr(>|t|)
(Intercept)	-1.238	0.083	-14.996	<2e-16
RelativeFrequency	-0.014	0.007	-2.027	0.044
SpeechRate	-0.057	0.006	-9.592	<2e-16
numberOfConsonantsdouble	0.165	0.051	3.244	0.001

The negative coefficient of RELATIVEFREQUENCY tells us that the higher the relative frequency, the shorter the duration of the prefix. This result is in accordance with the segmentability hypothesis and replicates for North American English the findings in Hay (2007), which investigated New Zealand English.

Unsurprisingly, a higher speech rate leads to shorter prefix durations. For NUMBEROFCONSONANTS we also find the expected effect: a double nasal across the morphemic boundary has a longer duration. Figure 1 illustrates the effects.

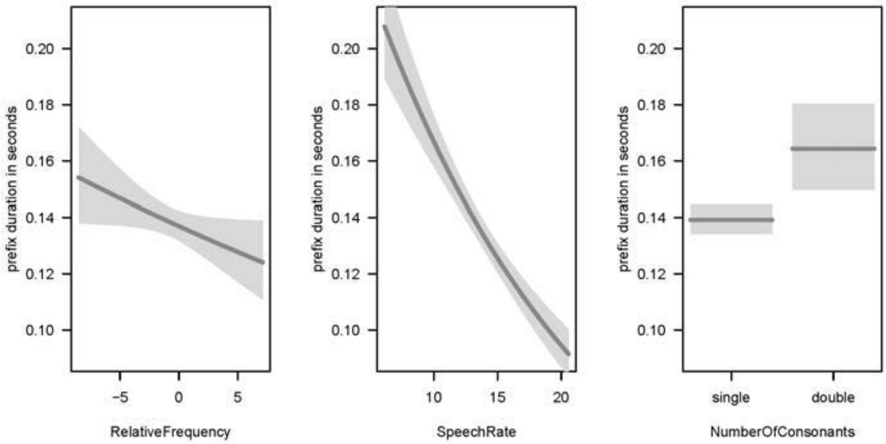

Fig. 1: Partial effects of final regression model for *un-*. The grey areas indicate the 95 percent confidence interval

4.2 The prefix *in-*

For the prefix *in-*, the following predictors were added to the baseline model: AFFIX, WORDFORMFREQUENCY, STRESSPATTERN, POSITION, and one of the four segmentability measures at a time. None of the four segmentability measures turned out to have a significant effect on prefix duration, only speech rate and the number of consonants turned out to be significant predictors.

4.3 The prefix *dis-*

Initial explorations of this data set showed significant correlations between the four segmentability measures. It was therefore not advisable to include them simultaneously in one regression. We therefore fitted four different models, each with one of the segmentability measures. In each of these models, the segmentability measures turned out to have a significant effect on prefix duration. Table 4 gives the statistics for the segmentability measures. In accordance with the segmentability hypothesis, words with a higher relative frequency show shorter durations (as shown by the negative coefficient in Table 4). Semantically transparent words have longer prefixes than semantically opaque words (shown by the positive coefficient of SEMANTICTRANSPARENCYBINARY and the negative coefficient of SEMANTICTRANSPARENCYRATING). Words with free bases have longer prefix durations than words with bound roots.

Tab. 4: Effects of segmentability measures in models with only one segmentability measure in addition to speech rate and number of consonants.

	Estimate	Std. Error	t value	Pr(>|t|)
RelativeFrequency	-0.003	0.001	-2.73	0.008
SemanticTransp.Binarytransparent	0.022	0.007	3.30	0.001
SemanticTransp.Rating	-0.011	0.003	-3.27	0.002
TypeOfBasefree	0.023	0.008	2.76	0.007

In addition to devising individual models each with one of the four segmentability measures we decided to use principal component analysis to derive a single segmentability measure, and then use this measure in a regression model to predict prefix duration. In a principal component analysis, the dimensionality of the data is reduced by transforming the different variables into so-called principal components. The transformation results in linear combinations of the predictors that are orthogonal to each other. The uncorrelated new linear predictors are called ‘principal components’.

In order not to overfit our models we first tested which of the noise variables had a significant influence. Apart from NUMBEROFCONSONANTS and SPEECHRATE (which were already in the baseline model), none of the noise variables had an effect on prefix duration. We then fitted a principal components regression model (using the `pcr` function of the `pls` package, Mevik and Wehrens 2007) with the four segmentability measures, NUMBEROFCONSONANTS and SPEECHRATE as predictors.

In the first step of this analysis the model yields six principal components. In a second step a regression model is fitted with all principal components as predictors. This model explains 43.2 percent of the overall variance. The first three components do most of the work, they explain 41.9 percent of the overall variance.

But what do these components mean? For the interpretation of the principal components it is useful to look at the correlations of the principal components with the original predictors. We therefore looked at how the first three components in our model relate to the original predictors. Table 5 gives the loadings of the original predictor variables on the first three principal components. The loadings are proportional to the correlations of the original variables to the principal components. In the table the most relevant loadings are given in bold print; very small loadings are not printed.

Tab. 5: Loadings of original predictor variables on the three most important principal components in the principal component regression model. (‘PC’ = principal component).

	PC1	**PC2**	**PC3**
RelativeFrequency	-0.426	0.150	-0.191
SemanticTransparencyBinarytransparent	0.514	0.220	
TypeofBasefree	0.475		-0.313
SemanticTransparencyRating	-0.547		
NumberOfConsonantsdouble	0.165	-0.624	0.672
SpeechRate		0.733	0.635

Principal component 1 (PC1) can be straightforwardly interpreted as tapping into morphological segmentability, as it correlates most strongly with all four segmentability measures (see top four rows of the table). The second and third components, i.e. PC2 and PC3, represent the effects of SPEECHRATE and NUMBEROFCONSONANTS.

In the regression model, PC2 is the strongest predictor, accounting for 28.5 percent of the overall variance. PC1, i.e. segmentability, comes in second, accounting for 8.3 percent of the overall variance. This shows that a combined measure of segmentability, as expressed by PC1, is indeed predictive of prefix duration, even in the presence of other influences. The effect of segmentability goes in the expected direction. As is clear from the correlations as given in Table 5, higher values of PC1 indicate a greater degree of segmentability. In the model, PC1 has a positive coefficient (estimate=0.007, standard error= 0.002, t=3.84, p<0.001), which means that increased segmentability goes together with increased prefix duration. Figure 2 plots the partial effect of segmentability. Derivatives that are more easily segmentable show longer prefix durations, in accordance with the segmentability hypothesis.

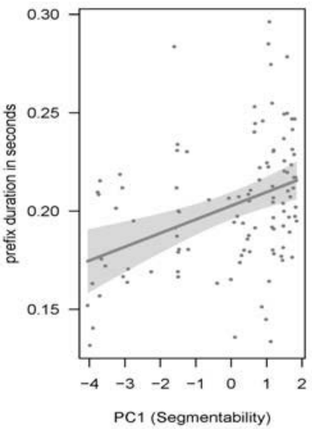

Fig. 2: Partial effect of segmentability (PC1) on prefix duration

4.4 The suffix *-ly*

For this affix relative frequency is the only segmentability measure that we can use since all *-ly* derivatives in the data set are fully transparent. Including relative frequency into the baseline model shows a non-significant effect of this variable (t=0.071, p=0.94). In other words, we do not find support for the segmentability hypothesis with words of this morphological category.

5 Summary and conclusion

Let us summarize our findings. Words with the prefixes *un-* and *dis-* show robust effects of segmentability in the predicted direction. For *un-* derivatives the only available segmentability measure was relative frequency. This measure turned out to have a significant effect on the duration of the prefix, such that more easily segmentable words showed longer prefix durations, in accordance with the segmentability hypothesis. With *dis-*, all four measures showed a significant effect on prefix duration individually. For this prefix we also devised a principal component analysis to derive a combined measure of segmentability. This combined measure was predictive for prefix duration in the way expected by the segmentability hypothesis. Based on the consideration that the interpretation of newly derived words needs to rely on morphological decomposition, we have indirect evidence that with these two prefixes newly derived words will tend to have longer prefixes in speech, and that, therefore, neologisms of these two morphological categories tend to differ phonetically from established words of that category.

The results for *un-* replicate Hay's (2007) results with a different data set and for a different variety of English. Our results for *dis-* are in line with those of Smith, Baker, and Hawkins (2012), in so far as these authors found longer prefix durations for prefixed words (e.g. *displeased*) as against pseudo-prefixed words (e.g. *displayed*). However, Smith, Baker, and Hawkins (2012) did not test for a potential effect of relative frequency.

The segmentability effect was not found for the two *in-* prefixes, nor for the suffix *-ly*. Overall, the present study thus replicates the mixed results obtained in previous studies. It is unclear which factors may be responsible for the non-emergence of durational effects of segmentability. Speculating on the basis of only these affixes, one could venture the hypothesis that such effects may only emerge beyond a certain threshold of decomposability. Both *un-* and *dis-* seem to be prefixes that are easily segmentable with the vast majority of their derivatives, while *in-* and *-ly* seem phonologically more integrated. For example, Raffelsiefen (1999) consistently assigns prosodic word status to *un-*, while *in-* is treated variably as either forming a prosodic word, or as being integrated into the prosodic word of its base, depending on the word in question. To our knoweledge, the prosodic word status of *-ly* is not treated in the literature, but we see no evidence for this suffix building a prosodic word of its own. Further research is necessary to investigate potential causes for the emergence or non-emergence of the segmentability effect in a given case.

To summarize, our results demonstrate that phonetic detail may help us to gain insight into aspects of lexical innovation that have been underexplored.

There is a continuum between highly idiosyncratic stored words at one end, and newly created words at the other end, and the innovation may manifest itself also at the level of phonetics, i.e. through the durational patterns of the words in question.

The present findings also have implications for morphological theory and morphological processing. The gradient effects of segmentability support theories in which morphological structure is conceived as gradient (see, for example, Hay and Baayen 2005; Plag and Balling, in press for discussion). Furthermore, our results call for processing models that are able to accommodate the presence of phonetic correlates of morphological structure in speech.

6 References

Aylett, Matthew & Alice Turk. 2004. The smooth signal redundancy hypothesis: A functional explanation for relationships between redundancy, prosodic prominence, and duration in spontaneous speech. *Language and Speech* 47(1). 31–56.

Baayen, Harald. 1989. *A corpus-based study of morphological productivity. Statistical analysis and psycholinguistic interpretation*. Amsterdam: Vrije Universiteit dissertation.

Baayen, Harald. 1996. The effect of lexical specialization on the growth curve of the vocabulary. *Computational Linguistics* 22. 455–480.

Baayen, Harald. 2008. *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge: Cambridge University Press.

Barker, Chris. 1998. Episodic *-ee* in English: A thematic role constraint on a new word formation. *Language* 74(4). 695–727.

Bauer, Laurie, Rochelle Lieber & Ingo Plag. 2013. *The Oxford reference guide to English morphology*. Oxford: Oxford University Press.

Beckman, Mary. 1986. *Stress and non-stress accent* (Netherlands phonetic archives 7). Dordrecht: Foris Publications.

Ben Hedia, Sonia & Ingo Plag. 2017. Gemination and degemination in English prefixation: Phonetic evidence for morphological organization. *Journal of Phonetics* 62. 34–49.

Ben Hedia, Sonia. In preparation. *Gemination and degemination in English affixation*. Düsseldorf: Heinrich-Heine-Universität Düsseldorf dissertation.

Berkovits, Rochele. 1993. Progressive utterance-final lengthening in syllables with final fricatives. *Language and Speech* 36(1). 89–98.

Blazej, Laura J. & Ariel M. Cohen-Goldberg. 2015. Can we hear morphological complexity before words are complex? *Journal of Experimental Psychology: Human Perception and Performance* 41(1). 50–68.

Boersma, Paul & David Weenink. 2014. *Praat: Doing phonetics by computer*. Version 5.4.04. http://www.fon.hum.uva.nl/praat/ (accessed 07 June 2017).

Breheny, Patrick & Woodrow Burchett. 2015. *Visreg: visualization of regression models*. https://CRAN.R-project.org/package=visreg (accessed 07 June 2017).

Bürki, Audrey, Mirjam Ernestus, Cédric Gendrot, Cécile Fougeron & Ulrich H. Frauenfelder. 2011. What affects the presence versus absence of schwa and its duration: A corpus analysis of French connected speech. *The Journal of the Acoustical Society of America* 130(6). 3980–3991.

Clark, John E. & Colin Yallop. [2]1995. *An introduction to phonetics and phonology* (Blackwell Textbooks in Linguistics 9). Oxford: Blackwell.

Cronbach, Lee J. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika* 16(3). 297–334.

Davies, Mark. 2008. *The corpus of contemporary American English: 400+ million words, 1990–present*. http://www.americancorpus.org/ (accessed 07 June 2017).

Fry, Dennis B. 1955. Duration and intensity as physical correlates of linguistic stress. *The Journal of the Acoustical Society of America* 27(4). 765–768.

Fry, Dennis B. 1958. Experiments in the perception of stress. *Language and Speech* 1. 126–152.

Gahl, Susanne. 2008. Time and thyme are not homophones: The effect of lemma frequency on word durations in spontaneous speech. *Language* 84(3). 474–496.

Giegerich, Heinz J. 2012. The morphology of *-ly* and the categorial status of 'adverbs' in English. *English Language and Linguistics* 16(3). 341–359.

Godfrey, John J. & Edward Holliman. 1997. *Switchboard-1 Release 2*. Philadelphia: Linguistic Data Consortium. https://catalog.ldc.upenn.edu/ldc97s62 (accessed 07 June 2017).

Hanique, Iris & Mirjam Ernestus. 2012. The role of morphology in acoustic reduction. *Lingue e Linguaggio* 11. 147–164.

Hanote, Sylvie, Nicolas Videau, Franck Zumstein & Philippe Carré. 2010. Les préfixes anglais *un-* et *de-*: Etude phonétique et acoustique. *Corela. Cognition, représentation, langage* HS–9. http://corela.revues.org/1081 (accessed 07 June 2017).

Harrington, Jonathan, Mary Beckman, Janet Fletcher & Sallyanne Palethorpe. 1998. An electropalatographic, kinematic, and acoustic analysis of supralaryngeal correlates of word and utterance-level prominence contrasts in English. In Robert H. Mannell & Jordi Robert-Ribes (eds.), *Proceedings of the 5th International Conference on Spoken Language Processing (ICSLP), 30 November –4 December, Sydney, Australia*, vol. 5, 1851–1854. Canberra: ASSTA.

Hay, Jennifer. 2001. Lexical frequency in morphology: Is everything relative? *Linguistics* 39(6). 1041–1070.

Hay, Jennifer. 2002. From speech perception to morphology: Affix-ordering revisited. *Language* 78. 527–555.

Hay, Jennifer. 2003. *Causes and consequences of word structure*. New York & London: Routledge.

Hay, Jennifer. 2007. The phonetics of *un-*. In Judith Munat (ed.), *Lexical creativity, texts and contexts* (Studies in Functional and Structural Linguistics 58), 39–57. Amsterdam & Philadelphia: John Benjamins.

Hay, Jennifer & Harald Baayen. 2005. Shifting paradigms: Gradient structure in morphology. *Trends in Cognitive Sciences* 9. 342–348.

Hay, Jennifer & Ingo Plag. 2004. What constrains possible suffix combinations? On the interaction of grammatical and processing restrictions in derivational morphology. *Natural Language & Linguistic Theory* 22(3). 565–596.

Johnson, Keith. 1997. *Acoustic and auditory phonetics*. Malden, Oxford & Victoria: Blackwell.

Jones, Daniel. 1959. The use of syllabic and non-syllabic *l* and *n* in derivatives of English words ending in syllabic *l* and *n*. *STUF - Language Typology and Universals* 12(1–4). 136–144.

Kemps, Rachèl, Mirjam Ernestus, Robert Schreuder & Harald Baayen. 2005a. Prosodic cues for morphological complexity: The case of Dutch plural nouns. *Memory & Cognition* 33(3). 430–446.
Kemps, Rachèl, Lee H. Wurm, Mirjam Ernestus, Robert Schreuder & Harald Baayen. 2005b. Prosodic cues for morphological complexity in Dutch and English. *Language and Cognitive Processes* 20. 43–73.
Kunter, Gero. 2016. *Coquery: A free corpus query tool.* http://www.coquery.org (accessed 07 June 2017).
Ladefoged, Peter. 2003. *Phonetic data analysis: An introduction to fieldwork and instrumental techniques*. Malden, Oxford & Victoria: Blackwell.
Ladefoged, Peter & Keith Johnson. ^{6}2011. *A course in phonetics*. Boston: Wadsworth Cengage Learning.
Ladefoged, Peter & Ian Maddieson. 1996. *The sounds of the world's languages. Phonological theory*. Oxford & Malden: Blackwell.
Laver, John. 1994. *Principles of phonetics* (Cambridge Textbooks in Linguistics). Cambridge: Cambridge University Press.
Lee-Kim, Sang-Im, Lisa Davidson & Sangjin Hwang. 2013. Morphological effects on the darkness of English intervocalic /l/. *Laboratory Phonology* 4(2). 475–511.
Lieberman, Philip. 1960. Some acoustic correlates of word stress in American English. *Journal of the Acoustical Society of America* 32(4). 451–454.
LimeSurvey Project Team & Carsten Schmitz. 2015. *LimeSurvey: An Open Source survey tool.* Hamburg: LimeSurvey Project. https://www.limesurvey.org/ (accessed 07 June 2017)
Machač, Pavel & Radek Skarnitzl. 2009. *Principles of phonetic segmentation* (Erudica 14). Prague: Epocha.
Marslen-Wilson, William D. 2009. Morphological processes in language comprehension. In M. Gareth Gaskell (ed.), *The Oxford handbook of psycholinguistics*, 175–193. Oxford: Oxford University Press.
Mevik, Bjørn-Helge & Ron Wehrens. 2007. The pls package: Principal component and partial least squares regression in R. *Journal of Statistical Software* 18(2). 1–24.
Mühleisen, Susanne. 2010. *Heterogeneity in word-formation patterns.* Amsterdam & Philadelphia: John Benjamins.
OED. 2013. *The Oxford English Dictionary online*. Oxford: Oxford University Press.
Oller, D. Kimbrough. 1973. The effect of position in utterance on speech segment duration in English. *The Journal of the Acoustical Society of America* 54(5). 1235–1247.
Payne, John, Rodney Huddleston & Geoffrey K. Pullum. 2010. The distribution and category status of adjectives and adverbs. *Word Structure* 3(1). 31–81.
Plag, Ingo. 1998. The polysemy of *-ize* derivatives: On the role of semantics in word formation. *Yearbook of Morphology* 1997. 219–242.
Plag, Ingo. 1999. *Morphological productivity: Structural constraints in English derivation* (Topics in English Linguistics 28). Berlin & New York: Mouton de Gruyter.
Plag, Ingo. 2003. *Word-formation in English* (Cambridge Textbooks in Linguistics). Cambridge: Cambridge University Press.
Plag, Ingo. 2014. Phonological and phonetic variability in complex words: An uncharted territory. *Italian Journal of Linguistics* 26(2). 209–228.
Plag, Ingo & Harald Baayen. 2009. Suffix ordering and morphological processing. *Language* 85(1). 109–152.

Plag, Ingo & Laura W. Balling. In press. Derivational morphology: An integrated perspective. In Vito Pirrelli, Wolfgang U. Dressler & Ingo Plag (eds.), *Word knowledge and word usage: A cross-disciplinary guide to the mental lexicon.* Berlin & New York: Mouton de Gruyter.

Plag, Ingo, Julia Homann & Gero Kunter. 2017. Homophony and morphology: The acoustics of word-final S in English. *Journal of Linguistics* 53(1). 181–216.

Pluymaekers, Mark, Mirjam Ernestus & Harald Baayen. 2005. Lexical frequency and acoustic reduction in spoken Dutch. *Journal of the Acoustical Society of America* 118(4). 2561–2569.

Pluymaekers, Mark, Mirjam Ernestus, Harald Baayen & Geert Booij. 2010. Morphological effects in fine phonetic detail: The case of Dutch *-igheid*. *Laboratory Phonology* 10. 511–531.

Price, Patti J. 1981. Sonority and syllabicity: Acoustic correlates of perception. *Phonetica* 37(5–6). 327–343.

R Development Core Team. 2014. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. https://www.r-project.org/ (accessed 07 June 2017).

Raffelsiefen, Renate. 1999. Diagnostics for prosodic words revisited: The case of historically prefixed words in English. In Tracy Alan Hall & Ursula Kleinhenz (eds.), *Studies on the phonological word* (Current Issues in Linguistic Theory 174), 133–201. Amsterdam & Philadelphia: John Benjamins.

Schulte, Marion. 2015. *The semantics of derivational morphology: A synchronic and diachronic investigation of the suffixes -age and -ery in English* (Language in Performance). Tübingen: Narr.

Schuppler, Barbara, Wim A. van Dommelen, Jacques Koreman & Mirjam Ernestus. 2012. How linguistic and probabilistic properties of a word affect the realization of its final /t/: Studies at the phonemic and sub-phonemic level. *Journal of Phonetics* 40(4). 595–607.

Smith, Rachel, Rachel Baker & Sarah Hawkins. 2012. Phonetic detail that distinguishes prefixed from pseudo-prefixed words. *Journal of Phonetics* 40(5). 689–705.

Sproat, Richard & Osamu Fujimura. 1993. Allophonic variation in English /l/ and its implications for phonetic implementation. *Journal of Phonetics* 21. 291–311.

Tucker, Benjamin V. & Mirjam Ernestus. 2016. Why we need to investigate casual speech to truly understand language production, processing and the mental lexicon. *The Mental Lexicon* 11(3). 375–400.

Umeda, Noriko. 1977. Consonant duration in American English. *The Journal of the Acoustical Society of America* 61(3). 846–858.

Venables, William N. & Brian D. Ripley. 4 2011. *Modern applied statistics with S* (Statistics and Computing). New York, Berlin & Heidelberg: Springer.

Videau, Nicolas & Sylvie Hanote. 2015. Pronunciation of prefixed words in speech: The importance of semantic and intersubjective parameters. *Lexis. Journal in English Lexicology* 9. http://lexis.revues.org/pdf/982 (accessed 07 June 2017).

Wells, John C. 3 2008. *Longman pronunciation dictionary*. Harlow: Pearson Education.

Wurm, Lee H. & Sebastiano A. Fisicaro. 2014. What residualizing predictors in regression analyses does (and what it does not do). *Journal of Memory and Language* 72. 37–48.