Morphological effects on fine phonetic detail: The case of Dutch *-igheid*

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Abstract

This study investigated the role of morphological structure in explaining pronunciation variation. The focus was on the Dutch derivational suffix -*igheid* (/əxhɛit/), which occurs in two types of words. In the first type, -*igheid* is analyzed as a single suffix. In the second type, there is a morphological boundary between -*ig* and -*heid*. The main research question was whether this difference is reflected in the duration of the /xh/ cluster. Two hypotheses were distinguished: one based on prosodic structure, which predicts that the cluster is shorter in the first type than in the second type, and one based on the informativeness of the affix given the morphological paradigm, which makes the opposite prediction. All occurrences of -*igheid* in a corpus of read speech were acoustically analyzed using Automatic Speech Recognition technology. The duration of the /xh/ cluster was found to be shorter in words of the second type than in words of the first type. This can be explained by the observation that words of the second type have sparser morphological paradigms, making the cluster less informative with respect to word identity. Furthermore, this finding shows that morphological effects on fine phonetic detail cannot always be explained by prosodic structure.

1. Introduction

The acoustic realization of words and affixes is characterized by immense intra- and inter-speaker variation. Some of this variation is due to noise in the execution of speech motor activities, and therefore lies outside the traditional research domain of (psycho)linguistics. On the other hand, many sources of variation have been uncovered that are directly relevant for linguistic theory. These sources include (but are not limited to) the position of word stress and sentence accent (e.g., Nooteboom 1972; Van Bergem 1993), the position of a word within a prosodic domain (e.g., Fougeron and Keating 1997), whether or not a word is part of a fixed expression (Binnenpoorte et al. 2005), the frequency and predictability of a word (e.g., Lieberman 1963; Hunnicutt 1985; Jurafsky et al. 2001; Pluymaekers, Ernestus, and Baayen 2005), and speaker characteristics such as sex, age and regional origin (e.g., Labov 1972; Byrd 1994; Keune et al. 2005). In the current study, we explore whether over and above these and other relevant factors, morphology also has a role to play in explaining pronunciation variation. We do this by investigating the phonetic implementation of the Dutch derivational suffix *-igheid* (/əxhɛit/).

1.1. The morphological structure of -igheid

Strictly speaking, the suffix *-igheid* consists of two separate suffixes: *-ig* and *-heid*. Hence, according to a standard morphological analysis, the noun *groenigheid* ‘greenishness’ is derived from the adjective *groenig* ‘greenish’, which is in turn derived from the adjective *groen* ‘green’. Insightful as such an analysis may be, it does not necessarily reflect the mental processes underlying the production of such a morphologically complex word. As Van Marle (1990) points out, morphological reanalysis may allow speakers to skip the second step and derive *groenigheid* directly from *groen*. A similar observation is made by Haspelmath (1995), who discusses the history of *-igheid*’s German equivalent, the suffix *-igkeit*. Originally, a word like *Müdigkeit* ‘tiredness’ was derived from *müdig*, which itself was derived from the base word *müde*. When the form ending in *-ig* fell out of use, speakers were more or less forced to analyze words like *Müdigkeit* as a combination of the base word and *-igkeit*, and this is when the new suffix *-igkeit* came into being. Now, *-igkeit* is also applied to adjectives that never had a form ending in *-ig*, such as *gefühllos* ‘senseless’ (*Gefühllosigkeit* ‘senselessness’).

For Dutch, the upshot of this reanalysis is that *-igheid* currently occurs in three types of words. In the first type, *-igheid* must be analyzed as a single suffix. For example, the word *vastigheid* 'security' is necessarily derived from *vast* 'solid', as *vastig* does not exist in Dutch. Hence, the morphological boundary in words of this type lies before *-igheid*. In words of the second type, the morphological boundary lies before *-heid*. This is for instance the case in a word like *zuinigheid* 'thriftiness', which has to be derived from *zuinig* 'thrifty' since *zuin* is not a word in Dutch. The third category of *-igheid* words consists of words that could be derived by adding *-igheid* to the base word, as well as by adding *-heid* to an existing form ending in *-ig*. Consider a word like *bazigheid* 'bossiness'. Since *baas* 'boss' and *bazig* 'bossiness' are both existing Dutch words, there is ambiguity as to whether *-igheid* functions as a single suffix or not. In the remainder of this paper, we will refer to words of the first type as +igheid words, to words of the second type as +heid words, and to words of the third type as ambiguous words. The term '*-igheid* words' is used to refer to all words ending in *-igheid*, regardless of their morphological structure.

1.2. The phonetic implementation of -igheid

With respect to the phonetic implementation of *-igheid*, most research has focused on the realization of the /xh/ cluster. This cluster, which does not occur morpheme-internally in Dutch, consists of two segments that are hard to distinguish perceptually. Therefore, one might expect the cluster to simplify, for example by deletion of /h/. Schultink (1962: 165) claims that /h/-deletion is indeed standard in the pronunciation of *-igheid*. On the other hand, Booij (in preparation) suggests that deletion of /h/ is especially likely in words in which *-igheid* is analyzed as a single suffix. In the current study, we examine whether the differences in morphological structure outlined above are reflected in the acoustic duration of the /xh/ cluster.

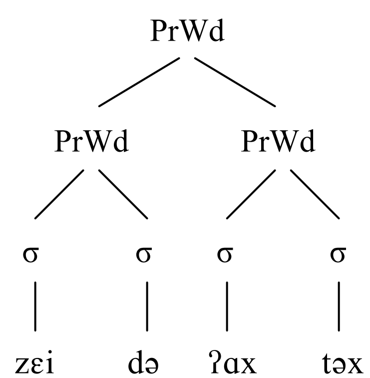
Recently, Hay (2003) demonstrated effects of morphological structure on the acoustic realization of the English phoneme sequence /tl/. Since this sequence does not occur within morphemes, Hay argues that listeners may use it as a cue to morpheme boundary. In addition, she claims that whether an affixed word is accessed as a whole or through its constituent morphemes is codetermined by the relative frequency of the affixed word compared to the base word. If the affixed word is more frequent than the base, it is more likely to be accessed as a whole. If on the other hand the base word is more frequent, identification is more likely to take place through the constituent morphemes. This suggests that the phoneme sequence /tl/ functions as a morphological boundary marker mainly in the second case, because it is in these words that morphological decomposition is most likely to take place. Hay predicts, therefore, that the acoustic realization of /t/ is longer in words like *softly*, which is less frequent than its base word *soft*, than in words like *swiftly*, which is more frequent than its base word *swift*. Her prediction is confirmed in a small laboratory experiment: /t/ is indeed longer in words like *softly* than in words like *swiftly*. This shows that it is possible to observe effects of morphological structure on acoustic realizations.

In the remainder of this introduction, we discuss two accounts of morphological structure that make different predictions about the simplification of the /xh/ cluster in *-igheid*.

1.3. A prosodic account

In the generative tradition, effects of morphology on acoustic realizations are believed to be mediated by phonology (e.g., Kenstowicz 1993: 60). In Prosodic Phonology (Nespor and Vogel, 1986), for instance, affixes can form prosodic words[2] of their own, allowing the morphological structure of a complex word to be reflected in its prosodic structure. An example of a Dutch affix that forms its own prosodic word is the suffix *-achtig* (Booij 1995: 47). The prosodic structure of the word *zijdeachtig* 'silky' looks as follows:

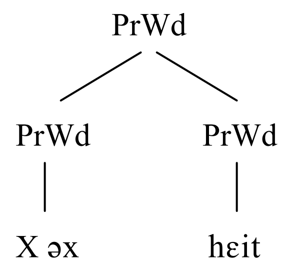
(1)



In (1), there is no resyllabification across constituent boundaries, as evidenced by the insertion of the glottal stop /ʔ/. Furthermore, Prevocalic Schwa Deletion does not apply. This example illustrates the basic assumption in Prosodic Phonology that morphological structure can affect phonetic form through mediation by phonology.

Now, let us consider the prosodic structure of *-igheid* words. According to Booij (1995: 47–52), *-heid* forms a prosodic word of its own, while *-ig* prosodifies with the stem. Therefore, it could be argued that all *-igheid* words have the following prosodic structure (X refers to the stem):

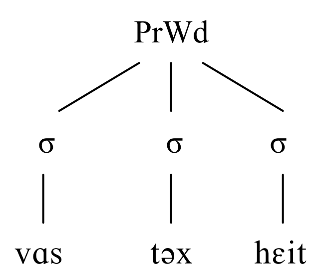
(2)



Such a structure works perfectly for words like *zuinigheid*, in which there is a clear morphological boundary between *-ig* and *-heid*. Since the /xh/ cluster marks a prosodic boundary in these words, it is unlikely to be simplified.

In some *-igheid* words, however, the suffix necessarily functions as a single unit (e.g., *vastigheid*). For these words the prosodic structure in (2) is less optimal, as it posits a prosodic word boundary between *-ig* and *-heid* even though there is no morphological boundary there. This misalignment between morphology and phonology could be resolved by assuming a different prosodic structure. Unfortunately, it is not possible to simply insert a prosodic word boundary before *-igheid*, as prosodic words in Dutch cannot start with schwa. Furthermore, there is resyllabification of the schwa with the preceding consonant. Therefore, a structure like (3) may be considered:

(3)



In (3), /h/ no longer occurs at the beginning of a prosodic word, which makes it a likely target for deletion. Consequently, a prosodic account predicts cluster simplification in +igheid words.

For words in which the morphological boundary can lie either before or after *-ig*, such as *bazigheid*, it is not self-evident which of the two prosodic structures applies. To determine the most likely morphological parse, Hay's (2003) concept of relative frequency can be used. This means that if the base word (e.g., *baas*) is more frequent than the *-ig* form (e.g., *bazig*), the morphological boundary is likely to be placed before *-ig*, making prosodic structure (3) the most plausible option. If, on the other hand, the *-ig* form is more frequent than the base, structure (2) can be assumed, as there is a morphological boundary between *-ig* and *-heid*. Since base words tend to be more frequent than *-ig* forms, the majority of words in this category will have a prosodic structure like (3). Hence, a prosodic account predicts that the /xh/ cluster will often be simplified in these words.

The predictions that a prosodic account makes about simplification of the /xh/ cluster are summarized in Table 1. Henceforth, we will refer to this set of predictions as the Prosodic Structure Hypothesis.

Table 1: Types of words ending in *-igheid* including examples, morphological structures, and predictions about the phoneme cluster /xh/ based on a prosodic account.

Type	Example	Morphological structure	Prediction for /xh/
+igheid	vastigheid 'security'	X + igheid	simplified
+heid	zuinigheid 'thriftiness'	Xig + heid	not simplified
ambiguous	bazigheid 'bossiness'	Mostly X + igheid	simplified

1.4. An information-based account

In the previous section, the focus was on the interplay between morphological and prosodic structure. However, morphology also governs the information flow within a word. Affixes can change the syntactic category or meaning of a word, which is what makes them informative for the listener. Informativeness has long been recognized as an important predictor of phonetic reduction, in that less informative linguistic units are found to be more reduced than more informative units (e.g., Lieberman 1963; Hunnicutt 1985; Jurafsky et al. 2001; Aylett and Turk 2004). Informativeness can be quantified in several ways, but most recent studies have used probabilistic measures derived from Information Theory (Shannon 1949). For example, Van Son and Pols (2003) developed a measure that estimates the individual contribution of a phoneme to word recognition by computing the reduction in the size of the cohort after that phoneme has been added to the signal.

For words containing *-igheid*, the cohort at the beginning of the suffix will mainly consist of other words from the same morphological paradigm. Therefore, it can be argued that affixes are more informative the more competitor words there are in the morphological paradigm. Table 2 gives an overview of the morphological paradigms typically associated with the three types of *-igheid* words.

Table 2: Summary of the morphological paradigms typically associated with the three types of *-igheid* words (X refers to the stem).

+heid	+igheid	ambiguous
	X	X
	X –e	X -e(n)
X -ig		X -ig
X -ige		X -ige
X -igheid	X –igheid	X -igheid
X -igheden	X –igheden	X -igheden
	+ compounds starting with X	+ compounds starting with X

First, let us consider words of the +heid category. Because these words have no base form without *-ig*, their paradigmatic neighborhoods are relatively sparse. For a word like *zuinigheid* 'thriftiness', this means that by the time the speaker has produced [zœyn], it is already clear that the word to be produced is either *zuinig* 'thrifty' or one of its morphological continuation forms. As a result, the /xh/ cluster is hardly informative with respect to word identity. One could argue that /h/ is more informative than /x/ because it distinguishes *zuinigheid* from *zuinige* 'thrifty', which ends in a /ə/. However, since /h/ and /ə/ can both be realized as voiceless vowels in Dutch, /h/ is not the most suitable segment to disambiguate between these two alternatives. Therefore, an account based on morphological informativeness predicts that in words like *zuinigheid*, the complete cluster /xh/ tends to be reduced.

For words in which *-igheid* is necessarily a single suffix, such as *vastigheid* ‘security’, a different prediction is made. The phoneme cluster /xh/ is very informative in *vastigheid*, as it signals to the listener that the word does not end after the existing form *vaste* ‘solid’. The same is true for words like *bazigheid* ‘bossiness’, which can be derived from *baas* as well as *bazig*. Given that /bazə/ exists as the plural form of *baas*, simplification of the /xh/ cluster would reduce the acoustic evidence for the morphological continuation form. Therefore, no cluster simplification is expected in these two word types.

Table 3 summarizes the predictions an information-based account makes with regard to simplification of the /xh/ cluster. This set of predictions will henceforth be referred to as the Morphological Informativeness Hypothesis.

Table 3: Types of words ending in *-igheid* including examples and predictions about the phoneme cluster /xh/ based on an information-based account.

Type	Example	Morphological paradigm	Prediction for /xh/
+igheid	vastigheid ‘security’	dense	not simplified
+heid	zuinigheid ‘thriftiness’	sparse	simplified
ambiguous	bazigheid ‘bossiness’	dense	not simplified

It could be argued that the information-based account does not really reflect morphological structure. However, the concept of informativeness outlined here is nothing more than the probabilistic consequence of the principle of proportional analogy, which is regarded as pivotal in structuralist as well as word-and-paradigm morphology (e.g., Blevins 2003). In word-and-paradigm morphology, the morphological unit is not the affix, but the word as it occurs in its morphological paradigm. The informativeness of an affix correlates with the density of the paradigm. As can be seen in Table 2, this density is much higher for words like *vastigheid* and *bazigheid* than for words like *zuinigheid*. Therefore, it is essential for successful communication that *vastigheid* and *bazigheid* are pronounced more carefully.

The present account also bears some resemblance to earlier work by Wright (1997), Scarborough (2004), and others. Wright (1997) found that words occurring in dense lexical neighborhoods (i.e., words that have a large number of competitor words differing in only one phoneme) were produced with more dispersed vowels than words occurring in sparse lexical neighborhoods. This can be explained by assuming that speakers hyper-articulate words from dense neighborhoods, as these words are easier to confuse with other words. Scarborough (2004) observed that more lexical confusability is also correlated with a higher degree of coarticulation. She explains this finding by pointing to the spreading of information that occurs when segments are coarticulated. By spreading phonemic information more evenly across the signal, speakers increase the likelihood of correct recognition, which is especially relevant if the intended word can easily be confused with other words.

These two studies differ from the current approach in one important aspect. Since they focused exclusively on monomorphemic words, no attention was paid to the role of morphological paradigms. These paradigms are pivotal in the current study, as our focus is on the discriminability of different morphological continuation forms.

In summary, we have presented two accounts of morphological structure that make different predictions with respect to the phonetic implementation of the phoneme cluster /xh/ in *-igheid*. In section 1.3, it was argued on the basis of a prosodic analysis that cluster simplification is *more* likely if *-igheid* is analyzed as a single suffix (Prosodic Structure Hypothesis). In section 1.4, it was pointed out that cluster simplification might actually be *less* likely if *-igheid* is a single suffix, because the cluster is more informative in such words (Morphological Informativeness Hypothesis). These two hypotheses were pitted against each other in a corpus study.

2. Method

2.1. Materials

The materials were taken from the subcorpus Library for the Blind of the Corpus of Spoken Dutch (Oostdijk 2000). This subcorpus comprises 100 hours of recordings of written texts, read aloud by trained speakers from the Netherlands and Flanders. Our main motivation for using read speech rather than spontaneous speech, which is also available in the corpus, was the superior sound quality of the recordings.

All 432 occurrences of *-igheid* in the subcorpus were selected for acoustic analysis. There were 164 different word types in the sample, 100 of which occurred only once. The two most frequent words in the sample were the +heid words *aanwezigheid* ‘presence’, which occurred 52 times, and *nieuwsgierigheid* ‘curiosity’, which occurred 22 times. For each word, the morphological type was determined on the basis of the morphological parse in the CELEX lexical database (Baayen, Piepenbrock, and Gulikers 1995).

2.2. Acoustic analysis

Acoustic analysis of the selected tokens was performed using Automatic Speech Recognition (ASR) technology. This was done for several reasons. First of all, it is possible to train an ASR device that bases its decisions purely on the characteristics of the acoustic signal, without reference to linguistic knowledge. This is very difficult for phoneticians, who are bound to be influenced by their knowledge of spelling and phonotactics (Vieregge 1987; Cucchiarini 1993). Second, ASR devices are perfectly consistent: Multiple analyses of the same acoustic signal will always yield exactly the same result. Finally, recent research has shown that the reliability of segmentations generated by an ASR system is equal to that of segmentations made by human transcribers (Vorstermans, Martens, and Van Coile 1996; Sjölander 2001), provided that a phonemic transcription of the signal is available to the ASR algorithm.

We trained a Hidden Markov Model (HMM) speech recognizer using the software package HTK (Young et al. 2002). To optimize the ASR’s performance on phonemic segmentation, we used context-independent, continuous density HMMs with 32 Gaussians per state (Kessens and Strik 2004). In total, 37 phone models were trained, representing the 36 phonemes of Dutch and silence. These models did not contain any information about the identity of surrounding speech sounds, let alone about higher-level linguistic structure. The training material was taken from the phonemically transcribed portion of the subcorpus Library for the Blind of the Corpus of Spoken Dutch. In total, the training sample consisted of 13328 read utterances produced by 134 different speakers. The combined duration of these utterances was 6 hours and 39 minutes.

The reliability of the ASR was examined in an independent pre-test. In this test, we compared the positions of phoneme boundaries placed by the ASR to the positions of the same boundaries placed by a trained phonetician. The test materials consisted of 189 words, spoken in isolation during a word naming experiment. The ASR-generated boundaries were obtained by providing both a parameterized acoustic signal and a phonemic transcription to a Viterbi algorithm, which determined the most likely segmentation of the signal given the pre-trained phone models. Comparison between the ASR-generated and hand-made segmentations revealed that 76% of the automatic boundaries were placed within 20 milliseconds of the corresponding hand-coded boundary. The main discrepancies were found in the beginnings of plosives and liquids, which were consistently placed earlier by the ASR than by the phonetician. If the automatic boundaries were shifted 10 and 7 milliseconds to the right, respectively, the percentage of boundaries placed within 20 milliseconds of each other increased to 81%. This level of accuracy is in accordance with international standards (Vorstermans et al. 1996; Sjölander 2001), and was considered sufficient for the present purposes.

For the acoustic analysis of the *-igheid* words, we manually excised the speech signals corresponding to these words from their sentence contexts. Subsequently, the signals were parameterized using Mel Frequency Cepstral Coefficients. Each parameterized signal was provided to the Viterbi algorithm, which automatically segmented the signal into phonemes on the basis of the CELEX transcription of the word. To correct for segmentation error, the beginnings of plosives and liquids were shifted 10 and 7 milliseconds to the right. By following this procedure, we obtained information about the durations of all individual segments in a word.

2.3. Statistical analysis and control variables

To see whether morphological type affected the acoustic realization of /xh/ while controlling for other relevant variables, we used multiple regression analysis. Regression analysis is a statistical technique that allows researchers to see whether a particular independent variable has an effect over and above other variables that may be relevant. Therefore, it is an extremely useful tool for analyzing corpus data. Furthermore, prior averaging is not necessary, as regression models are fitted to individual data points and not to means. Finally, it is easy to spot interactions between variables. If, for example, the effect of morphological type was to be limited to words with a high frequency of occurrence, this would surface as a significant type by frequency interaction in the regression model.

The dependent variable in the analysis was the duration of the /xh/ cluster, as measured by the ASR. Originally, we had planned to also investigate /h/-deletion, but a pre-test established that the presence or absence of /h/ after the fricative /x/ could not be reliably determined. Since deletion of /h/ is not likely to lead to a longer duration of the cluster as a whole, the predictions in Tables 1 and 2 also hold for the duration of /xh/.

The main independent variable was morphological type. In the analysis, two types were distinguished: +heid and +igheid. The ambiguous words were classified as +igheid words, for several reasons. First of all, 84% of the ambiguous words was likely to behave morphologically as a +igheid word, as the base word was more frequent than the *-ig* form (Hay 2003). Second, we did not observe significant differences between the +igheid and ambiguous types in any of the analyses we performed. Finally, the predictions concerning cluster simplification are the same for the two types, regardless of the hypothesis under investigation. Therefore, we decided to analyze them as a single category.

It might be argued, however, that the morphological structure of ambiguous words is not solely determined by the frequency ratio of the base word and the *-ig* form.

Control variables that were included as covariates were the speaker characteristics sex, age, and country of origin (Netherlands vs. Flanders), the rate of speech, the frequency of the word in the Corpus of Spoken Dutch, and whether the word was in utterance-initial or utterance-final position. Age was operationalized by subtracting 1900 from the year of birth of the speaker. Speech rate was estimated by counting the number of syllables per second in the utterance in which the *-igheid* word occurred. In the Corpus of Spoken Dutch, utterances are defined as stretches of speech that occur between audible pauses. Since in read-aloud speech, segment deletions are relatively rare, the syllable counts were based on the canonical pronunciations of the words in the utterance. Position in the utterance was controlled by means of two binary variables, Initial and Final, which were coded as either 'true' or 'false' for each token.

3. Results

We fitted a least squares model to predict the duration of the /xh/ cluster. To see whether morphological type had an effect over and above the control variables, it was entered into the model last. In a stepwise model selection procedure, only those variables were retained that showed a significant effect. Three data points were identified as outliers and removed from the data set. The model that was refitted to the remaining data showed a significant effect of morphological type on cluster duration ($F(1,423) = 10.49$, $p<0.005$). More specifically, the duration of the /xh/ cluster was shorter in words of the +heid type than in words of the +igheid type ($\hat{\beta} = -7.9$, $t(423) = -3.24$, $p<0.005$). This finding, which is illustrated in Figure 1, provides support for the Morphological Informativeness Hypothesis.

INSERT FIGURE 1 APPROXIMATELY HERE

In addition to morphological type, some of the control variables also showed significant effects. Clusters were shorter if the word was not in Initial ($\hat{\beta} = -13.7$, $t(423) = -2.75$, $p<0.01$) or Final ($\hat{\beta} = -12.3$, $t(423) = -5.07$, $p<0.0001$) position. Speakers from Flanders produced shorter clusters ($\hat{\beta} = -20.1$, $t(423) = -8.07$, $p<0.0001$), as did male speakers ($\hat{\beta} = -12.1$, $t(423) = -4.99$, $p<0.0001$). All in all, the regression model accounted for 26% of the variance in the duration of the /xh/ cluster.

4. Discussion

The current study investigated whether the fine phonetic detail of the Dutch suffix *-igheid*, canonically pronounced as /əxhɛit/, is affected by morphological structure. We conclude that this is indeed the case. The duration of the /xh/ cluster was found to be shorter in words in which *-igheid* is not a single suffix than in words in which it is. This finding lends support to the Morphological Informativeness Hypothesis outlined in section 1.4. According to this hypothesis, the duration of the cluster will be affected by its informativeness given the word's paradigmatic neighborhood. For words in which *-igheid* is not a single suffix, such as *zuinigheid*, the informativeness of the cluster is relatively low, since the possible base word (*zuin*) does not exist in Dutch and its paradigmatic neighborhood is relatively sparse. Thus, it is already clear at the end of [zœyn] that the word to be produced will be *zuinig* or one of its morphological continuation forms. As a result, the /xh/ cluster is relatively uninformative with respect to word identity, which manifests itself in durational shortening.

What makes this finding particularly interesting is that it cannot be explained on the basis of a prosodic account. The Prosodic Structure Hypothesis formulated in section 1.3 predicted that the /xh/ cluster would be longer in words like *zuinigheid*, because it serves as a morphological boundary marker there. Now that the exact opposite has been observed, we can conclude that, contrary to received wisdom, morphological effects on fine phonetic detail cannot always be accounted for by prosodic structure.

Our results also illustrate that intuitions about how a particular word or affix is pronounced can be misleading. Schultink (1962) claims that /h/ is likely to be deleted in all words containing *-igheid*, while Booij (in preparation) hypothesizes that /h/-deletion is especially likely if *-igheid* is regarded as a single suffix. The observation in the current study that simplification of the /xh/ cluster occurs especially in +heid words is at odds with both these intuitions. This once more underlines the importance of corpus data in phonological and phonetic research. We believe that corpus data are indispensable for confirming intuitions, or, as we did in the current study, for testing alternative hypotheses concerning the fine phonetic detail of acoustic realizations. However, corpus researchers need to make sure that possibly confounding variables are sufficiently controlled. If this cannot be done by means of experimental design, statistical techniques such as regression analysis should be used.

By saving effort on the articulation of uninformative linguistic units, speakers can free up resources for other cognitive tasks. Simultaneously, listeners might benefit from detailed knowledge about the resulting reduction patterns. Numerous studies have shown that listeners can use fine-grained structural phonetic differences between words to improve word processing (e.g., Davis, Marslen-Wilson, and Gaskell 2002; Hawkins 2003; Salverda, Dahan, and McQueen 2003; Warner et al. 2004; Kemps et al. 2005a; Kemps et al. 2005b; Ernestus and Baayen in press). Whether they also use the acoustic patterns reported in the current study can only be determined on the basis of a perception study. Our intuition, however, is that listeners might not be all that sensitive to durational differences in the phoneme cluster /xh/. Since the durational shortening takes place at a point where most ambiguity about the identity of the word has already been resolved, listeners will probably rely on other cues to determine which word they are hearing.

Although the current study was exclusively concerned with synchronic reduction, our results may also provide insights about how the pronunciation of *-igheid* will develop diachronically. Since we observed synchronic reduction in the duration of the /xh/ cluster in +heid words, it is not inconceivable that the cluster will also fall subject to diachronic reduction in these words.

With regard to future research, it would be interesting to examine whether patterns similar to the one described in the current paper can be found in other languages. An obvious candidate for such an investigation is the German suffix *-igkeit*, which resembles *-igheid* in terms of morphological structure and has the additional advantage that the two phonemes in the cluster of interest are acoustically well distinguishable. Further exploration of affixes like *-igheid* and *-igkeit* could shed more light on how morphology affects phonetic form without mediation by phonology.

Notes

1. This research was supported by Netherlands Organization for Scientific Research (NWO) grant number 360-70-130 to the third author.

2. For a definition of the prosodic word, see Nespor and Vogel (1986), Booij (1995), and Peperkamp (1997).

3. This decision was motivated by the observation that 84% of the ambiguous words was likely to behave morphologically as a +igheid word, as the base word was more frequent than the *-ig* form (Hay 2003). We checked whether analyzing the +igheid and ambiguous types as separate categories would have altered the nature of our results, but this was not the case. Furthermore, we did not observe significant differences between the two types in any of the analyses we performed.

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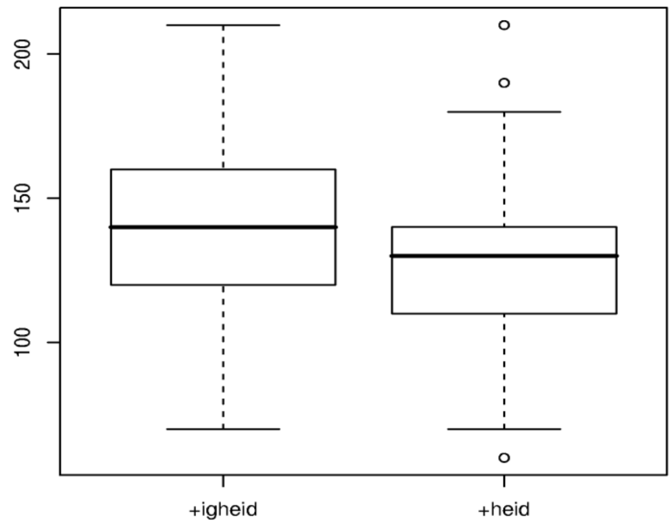

Figure 1: Boxplot of the duration of the /xh/ cluster (in milliseconds) as a function of morphological type.