

# THE ROLE OF MORPHOLOGY IN ACOUSTIC REDUCTION

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**ABSTRACT:** This paper examines the role of morphological structure in the reduced pronunciation of morphologically complex words by discussing and re-analyzing data from the literature. Acoustic reduction refers to the phenomenon that, in spontaneous speech, phonemes may be shorter or absent. We review studies investigating effects of the repetition of a morpheme, of whether a segment plays a crucial role in the identification of its morpheme, and of a word's morphological decomposability. We conclude that these studies report either no effects of morphological structure or effects that are open to alternative interpretations. Our analysis also reveals the need for a uniform definition of morphological decomposability. Furthermore, we examine whether the reduction of segments in morphologically complex words correlates with these segments' contribution to the identification of the *whole* word, and discuss previous studies and new analyses supporting this hypothesis. We conclude that the data show no convincing evidence that morphological structure conditions reduction, which contrasts with the expectations of several models of speech production and of morphological processing (e.g., `WEAVER++` and dual-route models). The data collected so far support psycholinguistic models which assume that all morphologically complex words are processed as complete units.

**KEYWORDS:** pronunciation variation, morphological structure, information load, lexical storage of morphologically complex words

## 1. INTRODUCTION

One common type of variation in spontaneous speech is the reduced pronunciation of words. For instance, *ordinary* may be pronounced as [ɑn.ɪ] and *apparently* as [p<sup>h</sup>ɛrɪ]. As reported by Johnson (2004), over sixty percent of the words in spontaneous American English deviate from their full form in at least one segment, and six percent of the words are pronounced with at least one syllable missing. This highly frequent phenomenon also occurs in other languages (see Ernestus and Warner, 2011, for an introduction to the

phenomenon).

Whether segments are reduced depends on many variables, like the rate of speech (e.g., Dalby, 1984), the speech style (e.g., van Son and Pols, 1999), the surrounding segments (e.g., van Bergem, 1994), and the predictability of the segment or word (e.g., Bell, Brenier, Gregory, Girand, and Jurafsky, 2009). Knowledge about these variables informs us about the speech production process and the nature of the mental lexicon.

In this paper, we investigate whether the production of reduced pronunciation variants in conversational speech is also affected by morphological structure. We formulate several hypotheses about how morphological structure may affect the degree of reduction and discuss new analyses and data from the literature bearing on these hypotheses.

Our first hypothesis concerns the effect of the repetition of morphemes on their degree of reduction. Previous studies have shown that words tend to be more reduced the more often they are repeated in a conversation (e.g., Fowler and Housum, 1987). If morphological structure plays a role in acoustic reduction, this may also hold for the repetition of morphemes. That is, morphemes may be more reduced if they are repeated, even in different words.

Our second hypothesis is based on previous studies which show that segments tend to be less reduced if they are more relevant for the identification of a linguistic unit (e.g., van Son and Pols, 2003). If morphemes play a role in acoustic reduction, we expect that a segment's degree of reduction also depends on its contribution to the identification of its morpheme in morphologically complex words. A segment is more important for the identification of a morpheme if it is its only segment (i.e., for single segment affixes, like the plural *s* in *words*) or its initial segment than if it is its final segment. Segments forming single segment affixes as well as morpheme-initial segments are therefore expected to be less reduced than segments at the end of longer morphemes (Losiewicz, 1992).

Importantly, words differ from each other in their morphological decomposability. The effect of a word's morphological structure on acoustic reduction is expected to depend on this morphological decomposability. Semantically opaque words (e.g., *department*) are more difficult to parse in their morphemes than semantically transparent words (e.g., *attachment*). Hay (2003), however, argues that also semantically transparent words can differ in their decomposability. The effect of a word's morphological structure on acoustic reduction is expected to be greater for words that are more easily decomposable.

Hay (2003) quantified decomposability as the relation of the frequency of the word to the sum of frequencies of the word's base and what

she called its inflectional variants (e.g., for *softly*, the sum of frequencies of *soft*, *softer*, and *softest*). If the word frequency is higher than the inflectional variants frequency, Hay assumes the word to be less decomposable and that its morphological structure only plays a minor role in processing. In contrast, if the inflectional variants frequency is higher than the word frequency, Hay assumes that the word is more easily decomposable. Then, morphological structure could play a more important role in speech production, and segments that are crucial for the identification of morphemes would be less likely to be reduced. This hypothesis has also been addressed by other researchers (Bürki, Ernestus, Gendrot, Fougeron, and Frauenfelder, 2011; Schuppler, van Dommelen, Koreman, and Ernestus, 2012), who all use different quantifications of decomposability.

If, contrary to the hypotheses formulated above, morphological structure has no role in reduction, the reduction of morphologically complex words is expected to be conditioned by the same factors as monomorphemic words. One such factor is a segment's importance in distinguishing the *complete* word from its competitors (henceforth *word information load*; e.g., van Son and Pols, 2003). Segments that are more relevant for the identification of the *complete* word are hypothesized to be less reduced.

After having discussed data bearing on these hypotheses, we discuss the implications for models of speech production. Models differ in the way they assume words are represented in the mental lexicon and processed during speech production: Some models assume that complex words are stored and processed as complete units (e.g., Bybee, 2001; Skousen, 1989), whereas other models assume that regular complex words are processed on the basis of their morphemes (e.g., Chomsky and Halle, 1968; Pinker, 1991; Taft and Ardasinski, 2006), or they combine the two ways of processing (e.g., Schreuder and Baayen, 1995; Levelt, Roelofs, and Meyer, 1999). We examined which existing psycholinguistic model best explains the available data on the role of morphological structure on acoustic reduction.

In short, this paper provides an overview and discussion of studies that investigated the role of morphological structure in acoustic reduction. Section 2 examines the question whether morphemes tend to be more reduced if they are repeated, even in different word types. Section 3 investigates the hypothesis that a segment is less reduced if it forms an affix by itself, while Section 4 focuses on the hypothesis that reduction is influenced by the word's morphological decomposability. In Section 5, we discuss data supporting the contrasting hypothesis that acoustic reduction is not conditioned by morphological structure, but rather by a segment's word information load. In addition to reviewing existing literature, we present new analyses of our own data. Section 6 discusses the implications of our

findings for several psycholinguistic models of speech production.

## 2. THE REPETITION OF MORPHEMES

Several studies have reported that words tend to be shorter if they are repeated in a spontaneous conversation (e.g., Fowler and Housum, 1987). If morphological structure plays an important role in acoustic reduction, we expect that this also holds for morphemes within complex words.

Viebahn, Ernestus, and McQueen (2012) examined whether Dutch past participles that occur closely together (but do not necessarily directly succeed each other) in casual speech tend to be reduced in the same degree. Importantly, they investigated if the similarity in reduction between these co-occurring words is affected by the similarity of their morphological structure. The authors differentiated three degrees of morphological similarity: identical words, different words starting with the same prefix, and completely different words also carrying different prefixes. This study focused on schwa in the prefix of 1848 past participles extracted from the Ernestus Corpus of Spontaneous Dutch (Ernestus, 2000) and the interview and read speech components of the Spoken Dutch Corpus (Oostdijk, 2002). Results showed that schwa tended to be short if the schwa in the preceding past participle was also short, but only if the two co-occurring past participles were tokens of the same word. That is, the schwa in, for instance, the past participle *gelopen* ‘walked’ tended to be as short as in a preceding token of *gelopen*, but not as short as in another preceding past participle, like *gefietst* ‘cycled’. Hence, repetition of just the prefix does not influence its degree of reduction.

The unit that plays an important role in speech production appears to be the complete complex word. This finding challenges the hypothesis that the morphological structure of complex words plays a large role in their pronunciation.

## 3. SINGLE SEGMENT AFFIXES

As explained in the Introduction, if morphological structure plays a role in acoustic reduction, we would expect that a segment tends to be less reduced if it forms an affix by itself than if it is positioned at the end of a longer morpheme. Losiewicz (1992) tested this hypothesis in a production experiment studying the correlation between the reduction of English word-final /t/ and /d/ and these segments' morphological status. The stimuli consisted of six minimal word pairs (see Table 1): One word of each pair

was a regular past tense verb ending in the suffix *-ed* (either pronounced as [t] as in *tacked* or as [d] as in *swayed*), in which /t/ or /d/ functioned as a single segment affix, while the other word was a monomorphemic homophone ending in stem-final /t/ or /d/. These twelve words were placed in lists and read aloud once by sixteen participants. Losiewicz found that the morphemic /t/ or /d/ of the regular past tense verbs was on average five milliseconds longer than the non-morphemic /t/ or /d/, which suggests that a segment's duration is affected by its morphological status (i.e., whether it forms a single segment affix or is the final segment of the stem).

Losiewicz selected her stimuli so that they had frequencies below 10 tokens in Francis and Kucera (1982) and Carroll, Davies, and Richman (1971). These frequency lists are based on relatively small corpora: one and five million word tokens, respectively. Currently, frequency lists are available based on larger corpora and consequently are more reliable. For instance, the CELEX database (Baayen, Piepenbrock, and Gulikers, 1995) provides counts based on 17.9 million word tokens. In Table 1, we list the word frequencies from CELEX. These counts show that for four of the six word pairs (in bold), the word with the shortest final segment has the highest frequency of occurrence<sup>1</sup>. Since many studies have shown that more frequent words tend to be more reduced (e.g., Bell, et al., 2009; Pluymaekers, Baayen, and Ernestus, 2005), the morphological effect found by Losiewicz may also be a word frequency effect.

WORD PAIR		WORD FREQUENCY		DURATION DIFFERENCE
<b>swayed</b>	<b>suede</b>	<b>25</b>	<b>58</b>	<b>+11</b>
<b>tacked</b>	<b>tact</b>	<b>5</b>	<b>76</b>	<b>+11</b>
<b>spayed</b>	<b>spade</b>	<b>2</b>	<b>51</b>	<b>+4</b>
<b>rapped</b>	<b>rapt</b>	<b>9</b>	<b>36</b>	<b>+3</b>
massed	mast	11	0	+3
bussed	bust	0	2	-2

TABLE 1. WORD PAIRS STUDIED BY LOSIEWICZ (1992) WITH THE ACCOMPANYING WORD FREQUENCIES FROM CELEX AND THE DIFFERENCE IN DURATION BETWEEN THE SUFFIX AND THE STEM-FINAL SEGMENT. FOR THE WORD PAIRS PRINTED IN BOLD, THE WORD WITH THE SHORTEST FINAL SEGMENT IS ALSO THE WORD WITH THE HIGHEST FREQUENCY OF OCCURRENCE.

A second study that examined the role of a segment's morphological status in acoustic reduction is Schuppler, van Dommelen, Koreman, and Ernestus (2012). Initially, the authors focused on word-final /t/ in all Dutch content words and extracted 5130 word tokens ending in /t/ from the Ernestus Corpus of Spontaneous Dutch. In contrast to Losiewicz, they did

<sup>1</sup> Frequency counts based on the 85 million words of the spoken component of the Corpus of Contemporary American English (Davies, 2008) also show that for four word pairs the most frequent word is the one with the shortest final segment.

not find that the morphological status of /t/ significantly influenced its presence or absence.

Schuppler and colleagues subsequently focused only on Dutch singular present tense verb forms ending in /t/. In regular Dutch verbs, the first person singular is equal to the stem of the verb (e.g., /fits/ *fiets* 'cycle'), and the third person singular is created by adding the suffix /t/ (e.g., /fits+t/ *fietst* 'cycles'). Importantly, if a stem ends in /t/ or /d/, this stem-final segment and the third person singular suffix /t/ are degeminated, which results in the pronunciation of a single /t/ (e.g., /nit+t/, [nit] *niet* 'staples'; /bid+t/ [bit] *biedt* 'offers'). If the stem ends in /d/, the third person singular is spelled with *dt*. This form therefore differs from the first person singular in orthography and the two forms can be easily identified in a corpus of spontaneous speech with orthographic transcriptions. Note that the crucial difference between the first and third person singular verb forms is that all first person forms end in a [t] that is part of the stem only (e.g., /bid/ [bit] *bied* 'offer'), whereas all corresponding third person forms end in a [t] that is part of the stem and is a suffix (e.g., /bid+t/ [bit] *biedt* 'offers'). Schuppler and colleagues analyzed 366 tokens. In agreement with Losiewicz (1992), they showed that suffix /t/ was significantly less likely to be absent than non-suffix /t/.

However, like Losiewicz's results, this finding by Schuppler and colleagues should be interpreted carefully. It is again based on a dataset consisting of a small number of tokens, which represent nine word types only. Moreover, this dataset is not balanced, as for the third person singular present tense verb forms *antwoordt* 'answers', *biedt* 'offers', and *snijd* 'cuts', it does not contain the corresponding first person forms (i.e., *antwoord*, *bied*, and *snijd*). In addition, the word *wordt* is often followed by a /d/-initial function word (e.g., *wordt dat* 'becomes that'). Due to degemination, this type of sequence is nearly always produced with only one alveolar stop, independently of whether the stop of *wordt* is present. Furthermore, the /t/ of the first person verb form *houd* 'love' is never produced in casual speech, which is reflected in informal writing (as in *ik hou van je* 'I love you'). Finally, the word type *vind* 'find' often occurs in highly frequent word combinations (e.g., *vind ik* 'believe I'), in which the /t/ is often absent, which is sometimes also reflected in writing (e.g., *vinnik*). These word combinations are likely to be lexicalized items, in which word-final /t/ is no longer present. Due to these problems with the dataset, Schuppler and colleagues' (2012) findings do not convincingly support the hypothesis that the morphological status of a segment influences its degree of reduction.

We also investigated the role of a segment's morphological status using the dataset from Hanique, Ernestus, and Schuppler (submitted), which

consists of Dutch past participles. Most Dutch regular past participles consist of the prefix *ge-* /xə/, a verbal stem, and the suffix /t/ (e.g., /xə+wɛns+t/ *gewenst* 'wished'). In past participles of verbal stems ending in /t/, /t/ is analyzed as resulting from degemination of the stem-final /t/ and suffix /t/ (e.g., /xə+prat+t/ [xəprat] *gepraat* 'talked'). We focused on word-final /t/ and analyzed 1166 tokens of past participles ending in /t/ (in 165 tokens, /t/ was part of the stem and the suffix, as in /xə+prat+t/ [xəprat] *gepraat* 'talked', and in 1001 tokens, /t/ only represented the suffix, as in /xə+wɛns+t/ *gewenst* 'wished'). All tokens were extracted from the Ernestus Corpus of Spontaneous Dutch and the interview and read speech components of the Spoken Dutch Corpus. Analyses showed that the morphological status of /t/ did not affect its duration, but it did affect its presence: Word-final /t/ was more likely to be absent if it was not part of the stem but only represented the suffix. This is unexpected given the hypothesis that segments forming single segment affixes are generally less likely to be reduced. We will return to this finding in Section 5.

This overview shows that, so far, no study has convincingly demonstrated an effect of a segment's morphological status on acoustic reduction. Some studies showed no effects of morphological status at all (the overall dataset of Schuppler et al., 2012, and our new analyses reported in this section), while the effects observed in other studies are open to alternative interpretations (Losiewicz, 1992; the verb form dataset in Schuppler et al., 2012).

#### 4. MORPHOLOGICAL DECOMPOSABILITY

As explained in the Introduction, morphological structure may only play a role in the pronunciation of words that are easily decomposable. Morphemes are more important in easily decomposable words, and only in these words, may segments at morpheme boundaries be expected to be less often reduced. In order to investigate this hypothesis, researchers have quantified decomposability in several ways.

According to Hay (2003), a word's morphological decomposability is reflected by the relation between its own frequency and the cumulative frequency of its inflectional variants. Hay hypothesized that if a word occurs more frequently than its variants, it is less decomposable and its segments at morpheme boundaries are therefore more likely to be reduced. Hay tested this hypothesis on the basis of /t/ in pairs of English adverbs (see Table 2), of which one word is more frequent than its inflectional variants (e.g., the frequency of *swiftly* is higher than the cumulative frequency of *swift*, *swifter*, and *swiftest*), and the other word is less frequent than its variants (e.g., the

frequency of *softly* is lower than the cumulative frequency of *soft*, *softer*, and *softest*). These adverbs were placed at the end of sentences, which were read aloud four times by six participants. For each participant, the duration of /t/ in the first production of a word was ranked with respect to the duration of /t/ in the first production of the other word in the pair. The second, third, and fourth productions were ranked similarly, and then average rankings were calculated for each word. Analysis of these average rankings showed that /t/ was more reduced in words that are less decomposable.

WORD	FREQUENCY		WORD	FREQUENCY	
	WORD	VARIANTS		WORD	VARIANTS
diligently	35	31	arrogantly	17	116
frequently	1036	396	recently	1676	1814
swiftly	268	221	softly	440	1464
exactly	2535	532	directly	1278	1472
listless	42	19	tasteless	30	1072

TABLE 2. WORD PAIRS USED BY HAY (2003). THE ACCOMPANYING WORD FREQUENCIES AND CUMULATIVE FREQUENCIES OF THE INFLECTIONAL VARIANTS ARE BASED ON CELEX.

There are, however, several reasons for interpreting these results with caution. First, as shown in Table 2, this study is only based on five word pairs. Second, the analyses are based on rankings of the durations rather than on the durations themselves. Third, it is unclear why Hay's decomposability measure does not take into account the frequency with which the stem of the adverb occurs in derived words (e.g., for *soft*, the frequency of *softness* was not taken into account).

Following Hay (2003), Schuppler and colleagues (2012) also investigated the correlation between decomposability and reduction. Their study analyzed the presence versus absence of affixal /t/ in Dutch third person singular present tense verb forms (e.g., /ʋon+t/ *woont* 'lives'). Their dataset consisted of 2110 verb forms extracted from the Ernestus Corpus of Spontaneous Dutch. They quantified a word's decomposability as the ratio of its word frequency (e.g., *woont* 'lives') and the frequency with which its stem occurs without affixal /t/, that is, the frequency of the first person singular present tense (e.g., *woon* 'live'). In contrast to Hay (2003), they found that /t/ was *more* likely to be absent in words that are more decomposable.

In order to investigate whether this dataset would also show an effect if the quantification of decomposability was more in line with Hay's definition, we re-analyzed the data. We quantified the decomposability of the third person singular present tense as the frequency of this word divided by the cumulative frequency of all words in the verbal paradigm (e.g., we investigated the effect of the frequency of *woont* relative to the sum of frequencies of *gewoond*, *wonen*, *wonend*, *wonende*, *woon*, *woonde*,

*woonden*, and *woont*). Since it is unclear whether decomposability is only sensitive to word forms containing exactly the same form of the stem, we calculated two measures of decomposability for irregular verbs: One based on only those verb forms that contain exactly the same form of the stem (e.g., *zoekt* 'searches' versus *zoek*, *zoeken*, *zoekend*, *zoekende*, and *zoekt*), and one based on all verb forms of the verbal paradigm (e.g., *zoekt* 'searches' versus *gezocht*, *gezochte*, *zocht*, *zoek*, *zoeken*, *zoekend*, *zoekende*, and *zoekt*). None of these relative frequencies significantly correlated with the presence versus absence of /t/. This raises the question whether decomposition does play a role, as claimed by Schuppler and colleagues (2012).

We observed that the decomposability measure defined by Schuppler and colleagues (e.g., the frequency of *zoekt* relative to the frequency of *zoek*) correlates ( $r = -0.19$ ) with the stem frequency of the verb form, that is with the sum of frequencies of the verb forms containing exactly the same stem (e.g., the sum of frequencies of *zoek*, *zoeken*, *zoekend*, *zoekende*, and *zoekt*). We examined which frequency measure (their decomposability measure or stem frequency) better predicts the absence of /t/ by conducting a regression analysis with both measures as predictors. We orthogonalized these measures by replacing stem frequency with the residuals of a regression model predicting stem frequency as a function of the decomposability measure. The model predicting absence of /t/ showed significant effects of both measures. We then orthogonalized the measures by replacing the decomposability measure with the residuals of a regression model that predicted this decomposability measure as a function of stem frequency. Absence of /t/ correlated with stem frequency but not with the residuals of the decomposability measure, which suggests that stem frequency better predicts reduction of /t/ than the decomposability measure. The stem frequency effect shows that /t/ is more likely to be absent at the end of words with higher stem frequencies. An explanation may be that all words belonging to highly frequent paradigms can be retrieved more easily and quickly, resulting in more reduced pronunciations.

Another reason for why the effect reported by Schuppler and colleagues may in fact not be driven by decomposability is that, of the 155 word types in their dataset, many of the third person singular present tense verb forms are homophones of the corresponding first person singular forms (e.g., /ʋet/ [ʋet] *weet* 'know' versus /ʋet+t/ [ʋet] *weet* 'knows') or differed substantially from the first person singular form (e.g., /hɛb/ [hɛp] *heb* 'have' versus /heft/ [heft] *heeft* 'has'). Schuppler and colleagues did not differentiate between the different syntactic functions of a form, and considered the frequency of each syntactic function to be the total frequency of the corresponding form. For homophones, the decomposability measure

therefore does not divide just the frequency of the third person singular by the frequency of the first person singular, but the total frequency of the form, that is, of the first, second, and third person singular by exactly this same sum frequency. Hence, it cannot be compared to the measure for non-homophone verb forms. For the irregular third person forms, such as *heeft*, there is another problem with the decomposability measure: Word-final /t/ is completely predictable given the preceding part of the word and therefore does not itself carry morphological information. If both the homophone and irregular items are excluded from the dataset, the decomposability measure used by Schuppler and colleagues is no longer significant. We conclude that whether the data analyzed by Schuppler and colleagues (2012) show morphological effects remains open to discussion.

We also examined possible effects of decomposability on the basis of word-final /t/ in Dutch past participles (Hanique et al., submitted). We used the two decomposability measures with which we re-analyzed the data provided by Schuppler and colleagues (2012, see above). The presence versus absence and duration of /t/ were not significantly affected by either of these relative frequencies.

Finally, Bürki, Ernestus, Gendrot, Fougeron, and Frauenfelder (2011) studied the influences of a word's morphological decomposability on the reduction of French word-internal schwa (as in /ʁə+diʁ/ *redire* 'to say again'). The authors extracted 4294 words with an internal schwa from the ESTER corpus (Galliano, Geoffrois, Mostefa, Choukri, Bonastre, and Gravier, 2005), which contains radio-broadcast news. Their measure for decomposability was different from the measures described above: Five native speakers of French were asked to assess each schwa on a five-point scale from being clearly morpheme-internal (as in /ʃəmɛ̃/ *chemin* 'way') to being clearly at a morpheme boundary (as in /ʁə+diʁ/ *redire* 'to say again'). For each word, the average value over assessors was used as a measure of the decomposability of the word. Bürki and colleagues observed that the presence versus absence and duration of schwa did not correlate with this decomposability measure.

In conclusion, so far, only two studies have reported an effect of decomposability and they did so by using different quantifications of decomposability. Since there are no clear theoretical reasons to prefer one quantification over another and since the effects observed may in fact not be morphological in nature, we conclude that so far the literature does not provide any convincing evidence for the role of a word's morphological decomposability in reduction.

## 5. WORD INFORMATION LOAD

Since we have, so far, found no convincing evidence that morphological structure plays a role in the reduced pronunciation of morphologically complex words, this section examines whether an important factor conditioning reduction in monomorphemic words may also be relevant for complex words. Previous studies (e.g., van Son and Pols, 2003) have shown that a segment tends to be less reduced the more it contributes to the identification of a word, and therefore to distinguishing the word from other words. If morphological structure does not play a role, this word information load hypothesis should also hold for segments in morphologically complex words: The less a segment contributes to distinguishing the complete word from other words, the more it may be reduced.

In Section 3, we presented data that support this hypothesis. We reported that word-final /t/ in Dutch past participles is more reduced if it only represents a suffix (i.e., it is not both part of the stem and a suffix). This would be unexpected if morphological structure played a role in reduction, since the /t/ is the affix' only segment, and reduction of /t/ would therefore lead to weaker acoustic cues to morphological structure. In contrast, this finding is expected if word information load is relevant: As most regular Dutch past participles end in suffixal /t/, this segment is highly predictable and thus does not contribute much to distinguishing the word from its competitors.

Pluymaekers, Ernestus, Baayen, and Booij (2010) investigated whether morphological structure or word information load is a better predictor for reduction of the cluster /xh/ in the Dutch word-final string /əxhɛit/ *-igheid*. Dutch words ending in *-igheid* either have the morphological structure stem+*igheid* (e.g., *vast+igheid* 'security') or stem+*heid*, in which case the stem ends in *-ig* (e.g., *zuinig+heid* 'thriftiness'). If morphological structure plays a role in reduction, /xh/ is expected to be less reduced in *+heid* words than in *+igheid* words, since in *+heid* words, the cluster /xh/ contains a morphological boundary between the stem and *-heid*, whereas in *+igheid* words, /xh/ is a cluster within the morpheme (Booij, 1995). If word information load plays a more important role, the opposite reduction pattern is expected. In *+igheid* words (like *vastigheid*), the cluster /xh/ eliminates inflectional variants (like *vaste* 'solid') and compounds (like *vasteland* 'main land' and *vastenavond* 'Mardi Gras'). In contrast, since stems ending in *-ig* (like *zuinig*) do not occur in compounds, *+heid* words based on these stems solely compete with a few inflectional variants (like *zuinige* 'thrifty' and *zuinigste* 'most thrifty'). As a consequence, the cluster /xh/ has a much lower word information load in stem+*heid* than

in stem+*igheid* and is therefore hypothesized to be more often reduced in +*heid* words. Pluymaekers and colleagues extracted 432 tokens ending in -*igheid* from the read speech component of the Spoken Dutch Corpus and demonstrated that the duration of /xh/ was significantly shorter in +*heid* than in +*igheid* words. This finding supports the word information load hypothesis.

A final study that we reviewed investigated the role of morphological structure and word information load in the weakening of word-final /s/ in Spanish (Torreira and Ernestus, in press). The authors distinguished three types of /s/: First, /s/ can be part of a stem as in *martes* 'Tuesday', in which case /s/ distinguishes the word from other words (e.g., *martes* 'Mars'). Second, /s/ can be a suffix that is redundant given the context, like the plural suffix in *años* 'years' when preceded by *cuatro* 'four'. In this case, the suffix's word information load is low. Third, /s/ can be a non-redundant suffix carrying new information, as the plural suffix in *quiero cosas* 'I want things'. Torreira and Ernestus extracted 930 tokens of word-final /s/ from the Nijmegen Corpus of Casual Spanish (Torreira and Ernestus, 2010). Type of /s/ neither affected the maximal difference in high-frequency intensity between the midpoint of /s/ and the beginning of the following vowel nor the duration of the low-frequency intensity dip in vowel-/s/-vowel sequences, but it significantly influenced voicing. Word-final /s/ tended to be voiced less often if it was part of the stem (48% voicing) or a non-redundant suffix (50%) compared to a redundant suffix (56%). This difference between redundant and non-redundant suffixes is best explained by word information load. It is also in line with previous studies showing that context plays a role in reduction. For example, Bell and colleagues (2009) have shown that words tend to be more reduced if they are more likely to occur given their context.

To summarize, one study directly addressed the question whether word information load (i.e., a segment's contribution to the identification of a word) or morphological structure better predicts acoustic reduction, and provided evidence in favor of an important role for word information load (Pluymaekers et al., 2010). The results of two other studies also appear to be better explained by the word information load hypothesis (Torreira and Ernestus, in press; our new analyses discussed in Section 3). We therefore conclude that word information load is more important in predicting degree of reduction than morphological structure.

## 6. DISCUSSION AND CONCLUSIONS

This paper provides an overview of studies from the literature and adds new

analyses on the role of morphological structure in acoustic reduction. In this section, we discuss our findings and relate them to models of speech processing.

In section 2, we first examined the role of morphological structure by investigating whether a morpheme tends to be more reduced if it is repeated. Previous studies have shown that complete words tend to be more reduced the more often they occur in the conversation (Fowler and Housum, 1987). The only study investigating whether this also holds for morphemes in complex words is by Viebahn and colleagues (2012). This study did not find a similar repetition effect for inflectional prefixes, unless the complete word was repeated. This suggests that the pronunciation process does not analyze morphologically complex words into morphemes and consequently that morphological structure does not play a major role in speech production.

This conclusion can also be drawn on the basis of the data discussed in Section 3. We examined whether segments forming single segment affixes are less likely to be acoustically reduced than segments at the end of longer morphemes, as segments forming single segment affixes are more important for the identification of the word's morphological structure. We carefully reviewed each study that has investigated this hypothesis in either production experiments or on the basis of speech corpora, including Losiewicz (1992), Schuppler and colleagues (2012), and our new analyses of data reported in Hanique and colleagues (submitted). We concluded that none of these provided clear evidence that a segment's morphological status affects its degree of reduction. In some studies, no effects of morphological status were found at all, and in others the effects found may not be morphological in nature.

We then examined whether acoustic reduction was influenced by a word's morphological decomposability (Section 4). Since words differ in how easily they may be decomposed into their morphemes, morphological structure may not affect the reduction of all words to the same extent. For instance, single segment affixes may only be less reduced than stem final segments if these affixes are part of highly decomposable words. Several studies have investigated this hypothesis. They quantified a word's decomposability by comparing the frequency of the word with the frequencies of all or some words that are morphologically related, or by asking native speakers to rate the word's decomposability. Two studies (Bürki et al., 2011 and our new analyses of the data reported in Hanique et al., submitted) did not observe decomposability effects. The other studies (Hay, 2003; Schuppler et al., 2012) reported an effect of decomposability, but in both studies the effects observed are open to alternative interpretations.

None of the four studies on morphological decomposability discussed in this paper provided a clear argumentation for why they operationalized decomposability in the way they did, and it is therefore difficult to choose between the measures. This is important, as the two datasets that show a correlation between decomposability and reduction (Hay, 2003; Schuppler et al., 2012) only do so if they quantify decomposability in different ways (i.e., decomposability was quantified as the word's frequency relative either to the frequency of all inflectional variants or to the frequency of the stem). To determine the role of decomposability in acoustic reduction, we therefore need a uniform definition of decomposability that is well-grounded in morphological theory and that can be easily quantified. Since this definition is currently not available and the experimental and corpus-based studies conducted do not provide convincing evidence for a role of decomposability in reduction, we conclude that, so far, the data on acoustic reduction do not support the hypothesis that morphological decomposability affects speech production.

Finally, in Section 5, we examined whether a segment's importance in identifying a word (i.e., its word information load) plays a more important role in acoustic reduction than a segment's importance for identifying a word's morphological structure. The studies that we found related to this issue (i.e., Pluymaekers et al., 2010; Torreira and Ernestus, in press) support the word information load hypothesis. This again suggests that the important units in speech production are words rather than morphemes.

Our review of the literature and our new analyses strongly suggest that morphemes do not play a major role in speech production. This challenges traditional models of morphological processing that assume that regular complex words are not stored in the mental lexicon, but are computed from their morphemes on the basis of rules (e.g., Chomsky and Halle, 1968; Pinker, 1991; Taft and Ardasinski, 2006). In addition, our results challenge speech production models such as `WEAVER++` (Levelt, Roelofs, and Meyer, 1999). In this model, the word to be produced (*lemma*) is first selected from the mental lexicon. If this word is morphologically complex, it is either treated as if it is monomorphemic (e.g., semantically opaque words), or it is processed via its morphemes (many completely regular complex words). In this model, morphological structure is therefore important in speech production.

This lack of clear evidence for the role of a word's decomposability in speech production has implications for theories assuming that a speaker tailors a word's degree of reduction to the listener's needs. Hay (2003) based her hypothesis that a word's decomposability affects its reduction on the dual-route models for word comprehension (e.g., Schreuder and Baayen,

1995). These models assume that complex words can be recognized via two routes: a decomposition route in which the word is decomposed into its morphemes, and a direct route in which the entire word is directly retrieved from the mental lexicon. Hay assumed that words are more likely to be processed via the decomposition route the easier they are to decompose. Decomposition would be facilitated if a word's pronunciation contained clearer cues to its morphological structure. Hay hypothesized that speakers therefore mark morphological structure more clearly in words that can best be recognized via the decomposition route, that is, in words whose stem often occurs in inflectional variants. The absence of convincing evidence for a role of a word's decomposability in reduction means that there is no clear evidence that speakers adapt their pronunciations of morphologically complex words in order to facilitate the listener's task.

The absence of data convincingly supporting a role of a word's decomposability in acoustic reduction also has consequences for the Hyper- and Hypospeech theory (Lindblom, 1990). This theory assumes that speakers prefer to hypo-articulate, unless this is harmful for the listener. The lack of clear evidence that speakers fine-tune the degree of reduction to their listener's needs strongly suggests that this theory does not hold for how speakers produce every individual segment in a word. This conclusion is in line with the finding by Bard, Anderson, Sotillo, Aylett, Doherty-Sneddon, and Newlands (2000), that speakers reduce repeated words independently of whether the current listener has heard the previous token.

We conclude that the words of the language are stored as complete units in the mental lexicon and are accessed directly. How easily the production of a segment is planned depends on several factors, including its predictability given the preceding part of the word and the preceding wider context (i.e., its information load). If this process of planning only takes a little time, the speaker can produce the segment more quickly, which may result in more reduced pronunciations (Bell et al., 2009). This view supports analogical models of speech production (e.g., Bybee, 2001; Skousen, 1989), in which morphological structures are not highly relevant for speech production. The connections between related words reveal the morphological structure, which the speaker can use in the formation of new morphologically complex words.

Importantly, our overview not only demonstrates that there is currently no evidence that morphological structure plays a substantial role in acoustic reduction, it also makes clear that several studies which present support for a role of morphological structure seem to do so because the effect that they report is not only correlated with morphological structure but also with, for instance, word information load. This again shows that

researchers should carefully consider conflicting explanations for the patterns in their data before concluding that one of them plays a role. Moreover, this shows that progress in research can only be made if researchers make their datasets available to other researchers. In this paper, we only re-analyzed datasets on which we had worked ourselves, as these were the only ones available to us.

In sum, the studies conducted so far show no convincing evidence for a role of morphological structure in acoustic reduction. Future studies first have to provide a better definition of morphological decomposability before we further investigate the role of morphological structure in speech processing. Moreover, they have to avoid confounds of morphological structure and word information load. Should these future studies not provide clear evidence for a role of morphological structure, this will have serious implications for the existing psycholinguistic models of speech production.

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