Chapter 5

THE BALANCE BETWEEN STORAGE AND COMPUTATION IN PHONOLOGY

Geert Booij

Abstract This article discusses two kinds of phonological evidence concerning the balance between storage and computation: allomorphy and phonological change. It is shown that even allomorphs that can be derived by a productive phonological rule are sometimes stored in lexical memory because these allomorphs are preserved although the relevant phonological process has been lost. Phonological processes that are subject to lexical diffusion also require lexical storage of the effects of these processes. This implies that the notions 'underlying form' and 'lexically stored form' should not be equated: surface forms are stored, and underlying forms are computed when they are needed for coining new words.

Keywords: Allomorphy, Auslautverhaertung, final devoicing, lexical diffusion, Optimality Theory, paradigmatic leveling, phonological change, rule opacity, underlying form, vowel lengthening, vowel reduction.

1. Introduction

The dominant view in classical generative phonology with respect to the kind of phonological information that is stored in the lexicon, can be summarized as follows: what can be computed should not be stored (cf. Kenstowicz, 1994, p.60). This view implies that predictable information about words is omitted from lexical representations. In case there are alternations in the shape of morphemes, the preferred solution is to assume one underlying form for all alternants, listed in the lexicon, and to derive the different surface allomorphs by means of one or more phonological rules. This kind of lexicon can be characterized as the Bloomfieldian lexicon, since Bloomfield, 1933, p.274 defined the lexicon as "a list of basic irregularities".

S. Nooteboom et al. (eds.), Storage and Computation in the Language Faculty, 133–156.

This view of the division of labour between lexicon and grammar has come under attack from a number of different perspectives. First, this view suffers from what has been called the 'rule/list fallacy' by Langacker, 1987, p.29: it is not necessarily the case that what can be computed by rule, should not also be stored in the lexicon. In the realm of morphology, Jackendoff, 1975 already argued that morphological rules have in principle two functions: they create new forms, but they can also function as redundancy rules with respect to existing complex words listed in the lexicon. This also applies to syntactic rules, for instance the rule of NP formation for English. There are adjective + noun phrases that function as names such as *yellow pages, red tape, green card, black hole, hard disk, little toe* which have an unpredictable meaning aspect, and hence have to be listed in the lexicon (Jackendoff, 1997, Chapter 7). Nevertheless, there is also a productive syntactic rule of English that creates new NP's that consist of an adjective and a noun.

This issue is quite an actual one for our view of the nature of the language faculty. In a recent paper, Clahsen, 1999 argues in favour of a dual structure of the human language faculty, a lexicon and a set of rules. His view is based on the analysis of inflectional rules of German, and he argues that it is only irregularities that are listed: regular forms are always derived by rule. As I pointed out in my commentary on this paper (Booij, 1999), this position cannot be completely correct. For instance, past participles of Dutch that are fully regular from the formal point of view must nevertheless be stored because of semantic irregularities. Examples of such participles are *gezet* 'fat' (from the verb *zetten* 'to put)', and *gesmeerd* 'fast, fluent' (from the verb *smeren* 'to smear'). The meanings of these participles are not predictable from their verbal stems, and therefore, they have to be lexically stored. Note, however, that this does not weaken Clahsen's view of the language faculty: his basic point is that there are rules besides lexical representations (contra the connectionist view), but in order to maintain that position he does not have to take the position that the outputs of regular processes are never stored.

There is also a wealth of psycholinguistic evidence that predictable information is sometimes stored in the lexicon. For instance, in the area of morphology, Baayen et al., 1997 showed that in Italian completely regular but frequent plural forms of nouns are stored in lexical memory.

In the realm of phonology similar considerations apply. A clear example is syllable structure. In most phonological analyses it is assumed that syllable structure should not be encoded in the lexical representation of words because it is fully predictable from the segmental structure of a word. The basic reasoning behind this view is that we should account

for the fact that in most cases syllable structure is not distinctive; hence it should not be stored. However, there is psycholinguistic evidence that the syllable templates of words are stored independently from their segmental structure. In speech errors one often finds that segments are exchanged that occupy the same position in syllable structure, for instance the onset position, as in the speech error *peel like flaying* instead of *feel like playing*. This shows that syllable structure must be lexically represented independently from segmental structure (Levelt, 1992, p.9-10).

The lexical presence of syllable structure is also presupposed in linguistic analyses of stress patterns that make use of the concept of syllable extrametricality. For instance, in Polish, a language with penultimate stress, there are a few words with antepenultimate stress, such as *uniwérsytet* 'university'. The last syllable of this word has to be marked as extrametrical in the lexicon in order to derive the correct stress pattern of this word. This implies that at least the last syllable (*tet*) is present as such in the lexicon. That is, the lexical presence of predictable syllable structure is implied by the necessity of lexical markings for stress.

In this article I will focus on two kinds of phonological evidence that throw light on the balance between storage and computation in the lexicon: allomorphy and phonological change. As to allomorphy, I will argue in section 2 that in many cases the surface allomorphs of a morpheme cannot be derived by phonological rule, and hence have to be stored in the lexicon, because there are no productive phonological rules that account for that allomorphy. In section 3 I will take a more radical step and argue that even when alternations are fully predictable by means of general and productive phonological rules, the facts of phonological change suggest that the outputs of such rules may nevertheless be stored in lexical memory. Both kinds of phenomena show that much more is lexically represented than what is assumed in classical generative phonology.

2. Allomorphy

Allomorphy is the phenomenon that morphemes exhibit certain alternations in form. The traditional generative approach is assuming one underlying form for a morpheme, and to compute the surface allomorphs by means of a set of rules.

In quite a number of cases, however, the actual variation in form, though predictable, is specific for only one or a small set of morphemes. For example, the Dutch diminutive suffix exhibits five surface forms,-*tje*,

-je, -pje, -kje and *-etje*. These five forms can be derived by rule from one underlying form by means of rules (cf. Trommelen, 1984, Booij, 1995). However, these rules have to mention the feature [+ diminutive] in their structural description because it is only the diminutive morpheme that triggers these rules. That is, they are, in terms of Anderson, 1974, morpholexical rules, and stand in opposition to phonological rules whose application is triggered by phonological conditions only, the so-called automatic phonological rules.

Recently, the insight has re-emerged that output constraints are essential for a proper account of phonological regularities. In Optimality Theory, such output constraints are seen as a set of universal constraints, ranked on a language-specific basis. This poses a problem for a phonological analysis of allomorphy because the equivalent of morpholexical rules in OT-phonology is a morpheme-specific ranking of constraints. Although the possibility of morpheme-specific constraint ranking is accepted by some linguists (cf. Plag, 1998; Raffelsiefen, 1999), it is quite implausible from the learnability point of view. Therefore, Mester, 1994, Kager, 1996, and Booij, 1998 proposed analyses in which the different allomorphs of a morpheme are lexically listed, and the choice of the correct allomorph follows from the set of ranked output constraints.

Let us make the discussion of this issue more concrete by having a look at the Dutch nominal suffix allomorphs *-er* /ər/ and *-aar* /aːr/ '-er'. Historically, both derive from the Latin suffix *-arius*. Synchronically, they are in complementary distribution: *-aar* occurs after verbal and nominal stems ending in schwa plus a coronal sonorant consonant, *-er* occurs in all other cases, except after /r/ where a third allomorph *-der* is chosen:

(5.1)

stem	*noun*
luist[ə]r 'to listen'	luister-aar 'listener'
twijf[ə]l 'to doubt'	twijfel-aar 'doubter'
rek[ə]n 'to compute'	reken-aar 'computer'
bel 'to ring'	bell-er 'ringer'
spin 'to spin'	spinn-er 'spinner'
klier 'to nag'	klier-der 'nagger'

Attempts to derive one of the allomorphs from the other have always caused problems: if /ər/ is the underlying form we need a rule that changes a schwa into /aː/ but this rule should apply to this suffix only. If we want to derive /ər/ from /aːr/ by means of a rule of vowel reduction that changes the full vowel /aː/ into a schwa, the problem arises that, although there is a rule of vowel reduction in Dutch (cf. Booij,

1995), it never applies to the last syllable of a word, whereas here the relevant vowel does form part of the last syllable. Therefore, we have to conclude that both allomorphs are to be listed in the lexicon. Thus, they function as competing suffixes, and the choice is made in terms of optimal outputs. In this case, the relevant output condition is that of Optimal Parsing: preferably, a word is parsed into trochaic feet. Given a verbal stem such as *bedel* /beːdəl/, the addition of the suffix *-er* would result in a rhythmic lapse because it will create a sequence of two unstressed syllables, of which the second cannot be parsed into a foot, and hence remains unparsed. On the other hand, if we add *-aar*, the syllable corresponding to this suffix can form a foot of its own because it has a full vowel, and hence it will have two feet, (beːdə) and (laːr).

The nice point of this solution is that, unlike the common underlying form approach, it also explains the reason behind the complementary distribution of these two suffixes: it is no coincidence that *-aar* is chosen after a stem that ends in a syllable headed by schwa because that is the only way to avoid a rhythmic lapse. In an approach in which we derive one allomorph from the (underlying form of) the other, there is no explanation of why the nature of the last vowel of the stem (full vowel versus schwa) plays a crucial role as a trigger of the alternation (Booij, 1998).

In sum, what I have done here so far is giving theoretical and empirical reasons for lexical listing of two allomorphs. Their status has thus become that of two competing affixes with a phonological similarity. Diachronically, there is a phonological relation between the two, but synchronically, this is no longer the case. This implies that as far as the balance between storage and computation in phonology is concerned, we move into the direction of storage: both allomorphs have to be stored, they have become competing morphemes.

This analysis is confirmed by the fact that the suffix *-aar* exceptionally also occurs in other phonological environments, i.e. after a syllable with a full vowel, as in *ler-aar* /leːraːr/ 'teacher' and *dien-aar* /dinaːr/ 'servant'. This is to be expected if *-aar* is a suffix of its own because affixes sometimes appear with other types of bases than the regular ones. Similarly, a number of diminutive nouns exhibit the 'wrong' allomorph, for instance *bruggetje* 'small bridge' (diminutive of *brug* 'bridge') instead of the regular *brugje*. Such a situation could never arise if the surface forms of the diminutive suffix were derived by automatic phonological rules. Thus, the existence of exceptional forms supports the individual listing of the five allomorphs of the diminutive suffix.

The implication is that an account of allomorphy in terms of derivation from a common underlying form is only possible if the rules that compute

the surface form are real phonological generalizations, that is: automatic phonological rules.

A shift of the burden of information for alternation patterns from rules towards the lexicon can also be found in Ortmann's analysis of consonant epenthesis in High Alemannic (Ortmann, 1998). In this dialect of German, spoken mainly in Switzerland, the consonant /n/ occurs after a set of vowel-final words, if the next word is vowel-initial, as in

(5.2) grösser wie-n-i 'taller than I'
bi-n-ene 'with them'

Historically, this /n/ is comparable to the intrusive /r/ in English: originally it was a word-final segment that was deleted before a consonant, and kept before a vowel. Synchronically, this /r/ has been reanalyzed in many varieties of English as an epenthetic /r/. In the German case, however, the occurrence of /n/ is lexically restricted. Ortmann's conclusion therefore is that the /n/ has to be present in the underlying representation. In other words, lexical storage of this /n/ is required.[1] The output condition onset ('do not have an empty onset') will then select the /n/-final allomorph before a vowel-initial word in the same phonological phrase. In short, this is a case where from a diachronic point of view there is a shift of information to the lexicon: the alternation between word-final /n/ and zero was once computable by rule, but now it has to be encoded in the lexicon. What is left for computation is the selection of the correct allomorph for each context, a selection performed by the universal constraint Onset. In other words, these German facts can be analyzed similarly to the lexically governed allomorphy of the English indefinite article *a/an* where the output condition Onset will prefer *an* before a vowel-initial word because the /n/ will fill the onset of the first syllable of the next word.

Another argument for the lexical listing of allomorphs in allomorphy that is governed by the Onset constraint (of which we saw an example for High Alemannic in the preceding paragraph), can be found in the French liaison facts (cf. Clements and Keyser, 1983). A word like *petit* 'small' has two surface forms, [pti] and [ptit]:

[1] Ortmann's specific solution is that the /n/ is treated as a floating segment not associated to a syllable position. If the next word begins with a vowel, it provides an empty onset position, to which the /n/ can be attached under resyllabification within the phonological phrase (Ortmann, 1998, p.67). Since the notion 'floating segment' requires the assumption of an independent X-tier in lexical representations to which not necessarily all segments are linked, and thus forms an addition to the theoretical machinery of phonology, I prefer a more straightforward solution, in line with what has been said above: the relevant words have two lexically listed allomorphs, one vowel-final and the other /n/-final.

(5.3) petit ami [ptit ami] 'little friend'
petit garçon [pti garsõ] 'little boy'

This alternation cannot be accounted for in terms of a word-final consonant deletion rule, but is best accounted for in terms of the word *petit* having two allomorphs, one with, and one without final /t/. The allomorph ending in /t/ is chosen if that /t/ can be attached to the empty onset position of the next vowel-initial word. Indeed, the syllable division of *petit ami* is (/pti/)(/ta/)(/mi/). In other words, it is the lexicon that accounts for the alternation between /t/ and zero, rather than a phonological rule or constraint. In sum, the adjective *petit* has two allomorphs, *peti* and *petit*, and selection of the right allomorph is done by the output condition Onset.

This allomorph selection interpretation of liaison is supported by the observation that there is a number of words for which the two allomorphs are phonologically too different to share an underlying form. A clear example is *beau* 'beautiful', which has the allomorph *bel* before a vowel-initial word; clearly, the form *bel* cannot be derived from *beau* by means of a phonological rule of French:

(5.4) un beau garçon 'a beautiful boy'
un bel ami 'a beautiful friend'

The stem *bel* also occurs in the feminine form *belle*, as in *une belle amie* 'a beautiful girl-friend'. The same universal output condition Onset will select *bel* as the optimal allomorph before vowel-initial words since it will result in the syllable sequence (/bɛ/)(/la/)(/mi/), with no empty onsets, whereas *beau ami* would have the syllable pattern (/bo/)(/a/)(/mi/), with a second syllable with an empty onset.[2]

The conclusion of this section is that there is a strong linguistic evidence for lexical storage of phonologically similar allomorphs of words, instead of deriving them from one common underlying form. This implies a shift from computation to storage with respect to the division

[2]This is an argument against the floating consonant analysis of word-final consonants of Clements and Keyser, 1983 because their analysis cannot generalize over *petit/peti* and *bel/beau*. In Perlmutter, 1998, an attempt is made to reduce the degree of lexical information required here by considering *bel* as identical to the feminine form of the adjective, *belle*. He then argues that the prosodic output condition Onset is ranked higher than the morphological Agreement condition that requires agreement in gender between a head noun and its modifying adjective. However, as Janda, 1998 pointed out in a commentary on Perlmutter's paper, there is no general principle for French that states that the agreement requirement can always be ignored in order to satisfy Onset, and that the possibility of using an allomorph that is similar to the feminine form is lexically governed, and also differs for different varieties of French. Therefore, for each word that exhibits C/V allomorphy, the allomorphs must be stored in the lexicon.

of labour between the phonological component and the lexicon. In the next section I will show how phonological change further strengthens this conclusion.

3. Phonological change

The main idea of this section is that phonological change provides a window on what is lexically stored versus what is computed by rule. In the previous section, we dealt with a number of alternations that have to be stored instead of being computed. In all of these alternations we have to do with alternations between phonemes or between phonemes and zero. What about allophonic properties? The traditional position in generative phonology is that allophonic properties are not lexically represented because they are predictable. There is, however, evidence, that even allophonic properties can be stored because they can survive after loss of the rule that accounted for that allophony.

A relevant case is that of vowel lengthening in open syllables in Early Middle Dutch. This process affected both simplex nouns and complex nouns, and even word+clitic combinations.

(5.5)

a.	*simplex nouns*	
	name 'name'	n[aː]me
	smake 'taste'	sm[aː]ke
	stave 'staff'	st[aː]ve
b.	*singular*	*plural*
	sch[ɪ]p 'ship'	sch[eː]p-en
	w[ɛ]g 'way'	w[eː]g-en
	h[ɔ]l 'hole'	h[oː]l-en
	oorl[ɔ]g 'war'	oorl[oː]g-en
	d[ɑ]g 'day'	d[aː]g-en
c.	*word + clitic*	
	saetic /sɑt ɪk/	[saːtɪk] 'sat I'

The singular-plural pairs in (5.5b) have been preserved in modern Dutch. This process of vowel lengthening is a manifestation of a much more general tendency in Germanic languages that stressed syllables must be heavy, i.e. cannot end in a short vowel, but contain minimally either a long vowel or a short vowel followed by a consonant (also known as Prokosch' Law).

In the first stage of this process in Early Middle Dutch (cf. Van Loon, 1986, p.89), the lengthening of the vowel was an allophonic process. In the course of time (probably in the 12th century), however, the length-

ened vowel was phonemicized, i.e. became an underlying long vowel. How do we know this?

The first evidence concerns short vowels followed by geminate consonants. These were protected from lengthening because the first half of the geminate closes the syllable. In the 12th century, degemination took place. Yet, the short vowels that thus ended up in open syllables, did not lengthen anymore, and so we find many words with short vowels followed by only one consonant such as *wikke* [ʊɪkə] 'vetch'. That is, the following development took place:

(5.6) VCV > V:CV (predictably long vowel) > V:CV (phonemic long vowel)
VCCV > VCCV (predictably short vowel) > VCV (phonemic short vowel)

These changes are illustrated by the following minimal pair (Van Loon, 1986, p.89):

(5.7) /ʊɪka/ 'week' /ʊɪkə/ /ʊeːkə/ (lengthened /ɪ/= /eː/)
/ʊɪkkia/ 'vetch' /ʊɪkkə/ /ʊɪkə/

The classical generative interpretation of this kind of phonemicization is as follows: the initial change is the addition of a rule of degemination to the phonological system of the adult speakers. This rule of degemination made the alternation between long and short vowels in the output forms opaque: vowel lengthening is ordered before degemination, and this is a non-bleeding order. The next generation of language users therefore interpreted the length contrast as a phonemic contrast, and hence the length contrast became part of the lexical representation. In addition, the process of vowel lengthening in open syllables disappeared.

A second kind of evidence for the phonemicization of these initially allophonic contrasts for simplex nouns is provided by the later process of schwa apocope (13th century). This phonological change did not affect the length of the vowel in the simplex nouns ending in schwa: after apocope the vowels of words such as *naam* 'name' (<name) and *smaak* 'taste' (<smake) stayed long. Again, vowel lengthening became opaque, and the next generation had to store the vowel length as part of the lexical representation. The phonemicization process even led to doublets such as *bar* 'raw' – *baar* 'ready (money)' and *staf* 'staff' – *staaf* 'bar', a process that can be expected given the phonemicization of vowel length.

This account in terms of rule opacity does not explain, however, why the alternation between long and short vowels was kept in certain cases such as those in the singular-plural pairs in (5.5b) above. When vowel lengthening disappeared, the length alternation should also have disappeared. The fact that it was kept for a number of words shows that

in these cases the plural forms must have been stored in their phonetic form, with a long vowel in the stressed syllable, at a time when the alternation was still governed by a phonological rule. In addition, it also shows that plural forms of nouns can be lexically stored, a conclusion that is confirmed by recent psycholinguistic evidence, as I already mentioned above (cf. Baayen et al., 1997).

The traditional generative account of this change would read as follows. Each new generation of speakers has to discover the rules of its native language on the basis of the phonetic outputs encountered. First, they will simply store the phonetic output forms of words. Once they have discovered the phonological regularities involved, they will replace each set of related phonetic output forms with one common underlying phonological form (so-called restructuring). If, for some reason, a particular phonological regularity (such as vowel lengthening in open syllables, the process discussed here) is not grasped by the new generation, there will be no restructuring: the stored phonetic forms will remain memorized as is, and if new words or word forms are coined, they will not be affected by that rule. Hence, the rule disappears, and only those words for which the different surface form had already been stored in lexical memory will keep that alternation.

However, this reasoning clearly presupposes that output forms are stored in the initial stages of acquisition. The question then is, why native speakers would change, and even erase that information about output forms in a later stage of acquisition, once they have discovered the phonological regularity involved. Given the vastness of human memory, there is no reason not to keep that information in lexical memory, and to use the phonological rule that can be discovered on the basis of related output forms for the computation of the phonetic shape of new words and word forms only. Thus, we get a natural division of labour between storage and computation: output forms, once heard, may be stored, and rules, once discovered, are used to interpret phonetically similar forms as instantiations of the same morpheme, and for the computation of the phonetic forms of new words.

For those words where there was no alternation involved, such as the words *weke* versus *wikke* given in (5.7) the assumption of storage in memory of the output forms by adult speakers is also necessary. Only if we assume that predictable length differences are stored, can we explain why the rule of degemination was added to the adult grammar: the addition of degemination has been made possible by the length difference, because the latter could now serve to keep words phonetically distinct. The language user is able to survey and inspect the phonetic output forms of words in his memory, and can thus conclude that the

distinction between single and geminate consonants is redundant given a concomitant distinction in vowel-length. The emergence of degemination can therefore be seen as the result of storage in speakers' memory of output forms. Similarly, the possibility of schwa apocope may also be seen as the result of storage of the phonetic output forms: since the vowel-length distinction was kept in memory, the word-final schwa could disappear. This then made it necessary to consider vowel length as information that is part of the lexical representation.

Given this analysis, we avoid constructing a complete gap between two generations of language speakers, and are not forced to assume that language change is only caused by the imperfect learning of the next generation that has to acquire the language on the basis of outputs. Language change is also an effect of the adult language user who is able to analyze the phonetic forms of words which are accessible in his memory.

The consequence of the loss of transparency of a phonological process (rule opacity) is that it is no longer possible to compute or store an underlying form for a word that differs from its phonetic form. A distance between phonetic form and underlying form is only possible in the case of surface-true transparent processes. In the case at hand this means that the plural forms of these nouns, with their long vowels, must be stored, also for new generations, since their phonetic forms cannot be computed.

Since the output form of the singular noun is the basis for computing the underlying form, the input for morphological operations, it is the short vowel that appears in such cases:

(5.8)

singular noun	*plural noun*	*derived word*	
gebr[ɛ]k 'handicap'	gebr[eː]ken	gebr[ɛ]kkig	'handicapped'
h[ɔ]l 'hole'	h[oː]len	h[ɔ]lletje	'diminutive'
sch[ɪ]p 'ship'	sch[eː]pen	sch[ɪ]pper	'skipper'
g[ɔ]d 'god'	g[oː]den	g[ɔ]ddelijk	'divine'
sp[ɛ]l 'game'	sp[eː]len	sp[ɛ]lletje	'diminutive'
w[ɛ]g 'road'	w[eː]gen	w[ɛ]ggetje	'diminutive'

In a number of cases the alternation that existed between singular and plural nouns disappeared after the loss of the rule of vowel lengthening (so-called analogical or paradigmatic leveling). This applies to, for instance, the following Dutch nouns which have a short vowel in their last syllable in both singular and plural forms:

(5.9)

bisschop 'bishop'	bisschoppen
lek 'leak'	lekken

gemak 'ease' gemakken
straf 'punishment' straffen

The traditional interpretation of these facts is that since the plural forms of these words were not stored, the regular forms with short vowels will show up after the loss of the rule of vowel lengthening. However, since the position is taken here that plural forms can be stored in their output form, the following interpretation is called for: the original plural forms of these words with long vowels did have a lexical representation of their own, but their frequencies, and thus their resting level of activation was not high enough to block the formation of a regular plural form without vowel lengthening, i.e. on the basis of the underlying form of the singular noun. This is also the point of view defended in Wetzels, 1981, p.95-97 and Wetzels, 1984, p.595 as to analogical leveling: analogical leveling is nothing else but the application of productive rules that are not blocked by the existence of stored forms.

3.1. Automatic rules and lexical storage

So far, our findings with respect to the lexicalization of vowel lengthening are in line with the conclusion of Wetzels mentioned above. However, he argued that paradigmatic leveling only takes place if rules are no longer automatic phonological rules, and hence require storage of allomorphs. Only if rules are no longer phonologically conditioned will the different allomorphs of a morpheme be lexically stored, which then may give rise to leveling by using the 'wrong' allomorph. Since, according to Wetzels, the outputs of automatic phonological rules are not stored, they will not lead to paradigmatic leveling. For instance, the alternations created by the automatic rule of devoicing of obstruents in coda position have, with a few exceptions to be discussed below, not been leveled in Dutch. Therefore, we will now have a more detailed look at coda devoicing.

It is an uncontroversial assumption within mainstream generative phonology that the effects of automatic neutralization rules are not encoded in lexical representations. For instance, Kenstowicz and Kisseberth, 1979, p.49 argue on the basis of the Russian rule of word-final devoicing of obstruents that it would be wrong to list both the allomorph with a voiced obstruent and the one with a voiceless obstruent in the lexicon, and to assume a selection rule for the allomorphs stated as follows:

(5.10) "If a morpheme has alternants that differ with respect to the voicing of a final obstruent, select the alternant with a final

> voiceless obstruent when the morpheme appears at the end of a word; otherwise, select the alternant with a voiced obstruent."

The authors then add that the "basic criticism is that this sort of analysis fails to adequately characterize the rule-governed nature of the voicing alternation in Russian" (p. 49). That is, such an analysis implies that two rules have to be assumed for Russian, a phonological rule of devoicing, and a morphological rule of allomorph selection.

Language change again provides a window on this issue: if we do not lexically store the outputs of a neutralization rule (with the effect that each output is a possible underlying form), we predict that paradigmatic leveling will not take place. I will therefore have a look at a process similar to Russian devoicing, coda devoicing of obstruents in Dutch. Final devoicing in Dutch is a productive generalization: voiced obstruents cannot occur in codas. If there are two allomorphs for a lexical item with an alternation between a voiced and a voiceless obstruent, it is generally assumed that the underlying form that is stored, is the form that ends in a voiced obstruent. If this voiced obstruent ends up in coda position, it is devoiced by the rule of final devoicing:

(5.11) rib [rɪp] / ribben [rɪbən] 'rib, sg/pl'
hoed [hut] / hoeden [hudən] 'hat, sg/pl'
slaaf [slaːf] / slaven [slaːvən] 'slave, sg/pl'
kiez [kis] / kiezen [kizən] 'molar, sg/pl'
vlieg [vlix] / vliegen [vliɣən] 'fly, sg/pl'

Interestingly, in some cases the alternation is lost. For instance, although we have the alternation *hand/handen* [hɑnt]/[hɑndən], there is an idiomatic phrase *bijdehand* 'lit. at the hand, bright' that functions as an adjective. One of its inflected forms in prenominal position is *bijdehante*, i.e. there is no alternation between voiced and voiceless obstruent anymore.

In Van Loey, 1964, p.54 the rise of forms such as *bijdehante* is interpreted as a case of paradigmatic leveling (analogy), which would suggest that the allomorph [hɑnt] of *hand* is stored. However, the problem for this account is that it does not explain why paradigmatic leveling almost never takes place with respect to effects of final devoicing. Another interpretation is therefore called for: the language learner only computes an underlying form that differs from the phonetic one if (i) the two words involved are related, and (ii) the two surface forms are relatable by means of a transparent rule. In the case of *bijdehand*, this adjective has no transparent formal relation to the word *hand* 'hand' with its plural form *handen*, and thus it will be stored with a final /t/. In other

words, we can only get underlying forms that differ from the surface forms if there is a transparent morphological relation between the words in which the different allomorphs occur (cf. Wetzels, 1981). Thus, the form *bijdehante* is not a counterexample to the claim made by Wetzels, 1981 that automatic phonological rules do not lead to leveling.

Another interesting case is the word *stad* [stɑd] 'town' with the irregular plural form *steden* [steːdən]. The plural noun not only exhibits vowel lengthening, but also vowel quality change, from /aː/ to /eː/. Consequently, the underlying form of *stad* is apparently computed as /stɑt/, as shown by new coinings such as the verb *statten* 'to do shopping in town' derived through conversion form the noun *stad* 'city', and the inhabitant name *Lelystatter* derived from the toponym *Lelystad*.

A similar phenomenon can be seen in Afrikaans for a number of nouns that have plural forms with lengthened vowels in Dutch. Apparently, the distance between *smid* 'blacksmith' and *smeden* (plural), for instance, is too large for speakers of Afrikaans, and thus they do not conclude to a common stem /smɪd/. Thus, the lexical form of *smid* will be /smɪt/ rather than /smɪd/, and consequently the regular plural *smitten* has arisen.

(5.12)	*Dutch*:	*Afrikaans*:	
	smid [smɪt]	smit [smɪt]	'smith, sg'
	smeden [smeːdən]	smitten [smɪtən]	'smith, pl'

The point here is that precisely the nouns with the unproductive vowel length alternation exhibit paradigmatic leveling with respect to the still transparent rule of coda devoicing.

In the case of the words with the vowel length alternation discussed above, there is also internal evidence for the storage of the effect of coda devoicing in the lexical entry, because vowel length plays a role in the distribution of fricative consonants. The generalization is that /v/ and /z/ only occur after long vowels, the *v/z*-constraint.[3]

[3]There are four exceptions: the loan words *mazzel* 'good luck', *puzzel* 'puzzle', *razzia* 'idem', and the name for railway kiosks *wizzl*, a form intentionally coined as a marked form with a high attention value.

Interestingly, we find the following alternations

(5.13)

nouns		
graf [ɣrɑf]	graven [ɣraːvən]	'grave, sg/pl'
hof [hɔf]	hoven [hoːvən]	'court, sg/pl'
glas [ɣlɑs]	glazen [ɣlaːzən]	'glass, sg/pl'
staf [stɑf]	staven [staːvən]	'staff, sg/pl'
verlof [vərlɔf]	verloven [vərloːvən]	'permission, sg/pl'
verbs, past tense, sg/pl		
las [lɑs]	lazen [laːzən]	'read'
genas [ɣənɑs]	genazen [ɣənaːzən]	'cured'
gaf [ɣɑf]	gaven [ɣaːvən]	'give'
vergaf [vərɣɑf]	vergaven [vərɣaːvən]	'forgave'
noun-verb pairs		
draf [drɑf] 'trot'	draven [draːvən]	'to trot'
lof [lɔf] 'praise'	loven [loːvən]	'to praise'

In all these cases, short vowels are followed by a voiceless fricative, whereas long vowels are followed by a voiced fricative. In other words, all allomorphs obey the constraint on the distribution of /v/ and /z/. In these cases, the voicelessness of the final obstruent is also part of the underlying form, although this information is predictable, and although these obstruents alternate with voiced ones. We know this on the basis of the forms of complex words derived from such nouns: these words are derived either from a form with short vowel + voiceless obstruent, or from a form with long vowel + voiced obstruent; the combination short vowel + voiced obstruent does not occur:

(5.14)

—	gl[aː]zenier 'stained glass artist'	*glazzenier
h[ɔf]elijk 'polite'	h[oː]veling 'courtier'	*hovveling
best[ɑf]ing 'staff'	st[aː]ven 'to prove'	*bestavving
l[ɔf]elijk 'praiseworthy'	l[oː]ven 'to praise'	*lovvelijk

On the other hand, if the noun ends in a stop or a velar fricative, this restriction does not apply, and morphology can apply to underling forms with a voiced stop:

(5.15)

singular	*plural*	*derived word*	
god	goden	g[ɔ]ddelijk	'divine'
bad	baden	b[ɑ]dderen	'to bathe'
weg	wegen	w[ɛ]ggetje	'small road'

The v/z-constraint thus restricts the distance between phonetic form and underlying form.

Van Loey, 1964, p.54-55 also mentions a number of cases in which leveling in favour of the allomorph with voiceless obstruent took place, where no additional alternations are involved that make the two allomorphs different in other respects as well. Examples from 17th century Dutch are:

(5.16) gewaet 'dress' / gewaden 'pl.' > gewaeten
cieraet 'ornament'/ cieraden 'pl.' > cieraeten

In these cases the allomorphs with final [d] have been restored in modern Dutch.

There are also cases in present-day Dutch of this kind of leveling. An example is the adjective *boud* 'bold'. Originally, the inflected form of this adjective is *boude*, but most speakers of Dutch say *boute*, which shows that the alternation d/t has been leveled out. What these examples show is that leveling in favour of the allomorph with voiceless obstruent is possible. This kind of leveling can be due to imperfect learning: the language user did not yet compute the correct underlying form of the noun on the basis of the alternation between singular and plural form, although the alternation is transparent. Therefore, the underlying form is identical to the phonetic form of the singular noun.

We may thus hypothesize that we store phonetic forms and that underlying forms are computed on the basis of stored phonetic forms (a similar position is taken in Leben, 1979). Underlying forms will only differ from phonetic forms in so far that difference follows from transparent phonological rules. If the distance between two forms is too big either semantically (the case of *bijdehand*) or because the formal differences are too big (*stad-steden* and the Afrikaans cases), the underlying forms will not differ from the surface forms. A structural constraint such as the Dutch *v/z*-constraint will also block the computation of an underlying form that is different from the surface form of a word, even though there is an automatic alternation involved.

3.2. Lexical diffusion

In the early stages of generative phonology, phonological change was seen as the addition of a rule at the end of the grammar. That is,

the lexical representations do not change, but the corresponding surface form is affected by the application of the added rule. It is only the new generation that will have different lexical representations with the effect of the added rule lexically encoded, except when it is a rule that creates alternations. In the latter case, lexical representations will not necessarily change.

A problem for this view is that phonological changes in progress often affect lexical representations but are also simultaneously the source of phonological alternations. For instance, Dutch is subject to a process of /d/-weakening in which intervocalically, /d/ is replaced with the glide /j/ before a following, suffix-initial schwa (Booij, 1995, p.90). This causes alternations of the following type:

(5.17) goed 'good', inflected form goed-e,
phonetic form [ɣudə] or [ɣujə]
rood 'red', inflected form rod-e,
phonetic form [roːdə] or [roːjə]

Application of this allomorphy creating rule of /d/-weakening is lexically governed. For instance, it does not apply to the plural form of *hoed-en* 'hats' [hudən]: the phonetic form [hujən] is impossible. Weakening also applies optionally to the derived adjective *goed-ig* 'good-natured' [ɣudəx] or [ɣujəx], but obligatorily to the derived noun *goeierd* [ɣujərt] 'good-natured person': the form [ɣudərt] is impossible. But other adjectives with stem-final /d/ do not always allow weakening; the adjective *wreed* 'cruel', for instance, does not have the inflected form [wreːjə] for *wrede*, the only form possible is [wreːdə]. Similar observations apply to processes such as /d/-deletion in Dutch (Booij, 1995, p.90). The lexically governed nature of these alternations implies that they must be stored lexically, even in the case of morphologically completely regular inflected forms of adjectives such as *goed-e*.

The facts of *d*-weakening support the claim of Kiparsky, 1988; 1995 that it is lexical, i.e. neutralizing rules that exhibit lexical diffusion, since the distinction between /d/ and /j/ is phonemic in Dutch. What is essential from the perspective of this paper is that they support the view that information provided by rule and information that is lexically stored are not exclusive with respect to each other.

These allomorphy facts imply that the recognition system of the language user must have a certain robustness because (s)he has no problems in relating *goed* to *goeie* and *goeierd* notwithstanding the phonological differences in the lexical representation of the shared part of these words, the lexical morpheme *goed*. That is, apparently the phonetic forms of a morpheme do not have to be computed by rule from a common under-

lying form in order to be recognizable as allomorphs of that morpheme (contra Lahiri and Marslen-Wilson, 1992).

In the case of /d/-deletion an intervocalic /d/ is deleted, and replaced with a predictable hiatus filling glide. For instance, the inflected adjective *oud-e* 'old' can be pronounced as [ɑudə] or [ɑuʋə]. Both forms must be stored because it cannot be predicted which forms allows for *d*-deletion. The phonetic difference even correlates with a semantic difference in the case of the A+N phrases *oude hoer* [ɑudəhuːr] 'old whore' (the literal meaning) versus *ouwe hoer* [ɑuʋəhuːr] 'talkative person'.

Labov, 1981; Labov, 1994 proposed to distinguish two types of phonological change: change that is phonetically gradual, and affects all relevant words, and change that is phonetically abrupt, replaces a phoneme with another one, and is lexically gradual, i.e. exhibits lexical diffusion. Kiparsky, 1988 argued that the distinction between phonetically gradual and phonetically abrupt changes coincides with the distinction between postlexical and lexical phonological rules. The rules of /d/-weakening and /d/-deletion can indeed be considered lexical rules since they are neutralizing. As expected, they have exceptions, and thus exhibit lexical diffusion. Lexical diffusion always creates surface opacity for rules since the speaker will find forms that have not undergone the rule. Therefore, as stated above, opacity will lead to lexical storage in the sense that for each phonetic form of such words a distinct lexical entry has to be created. This in its turn explains why semantic distinctions may correlate with phonological differences, as in the pair *oude hoer / ouwe hoer* discussed above.

What about the effects of postlexical rules? The usual assumption (cf. Kiparsky, 1988, p.399) is that the effects of such rules are not encoded in lexical representations. In recent work, Bybee (to appear, a) has questioned these assumptions. She argues that a change may be both phonetically and lexically gradual. This implies that the effects of such gradual changes must be lexically stored, in the lexical representations of individual words.

Vowel reduction in Dutch (Booij, 1982; 1995; Van Bergem, 1995) is a potentially interesting phenomenon in this respect because it has both lexical and postlexical properties. The basic generalization is that at the phonetic level all unstressed vowels are affected by reduction in the sense that their actual realisation can be quite far away from the target values of the acoustic parameters of these vowels (Van Bergem, 1995). In addition, there is a lexical process of vowel reduction of vowels in unstressed (non-word-final) syllables that has already affected many words whose full vowels have been replaced with schwa, for instance:

(5.18) tel*e*vísie 'television'
álg*e*bra 'algebra'
ser*e*náde 'serenade'
r*e*cláme 'publicity'
b*e*tón 'concrete'
rep*e*títie 'rehearsal, test'
conf*e*réntie 'conference'

Morover, there is also a large number of words that exhibit vowel reduction in more casual speech only, i.e. there is still alternation:

(5.19) banáan 'banana' [baːnaːn] / [bənaːn]
polítie 'police' [poːlisi] / [pəlisi]
minúut 'minute' [minyt] / [mənyt]

These facts of vowel reduction nicely fit into Kiparsky's two-stage theory of phonological change: "... the phonetic variation inherent in speech, which is blind in the neogrammarian sense, is selectively integrated into the linguistic system and passed on to successive generations of speakers through language acquisition" (Kiparsky, 1995, p.642). Vowel reduction, originally a purely phonetic process motivated by ease of articulation, could become a lexical rule, subject to lexical diffusion, because the schwa is a phoneme. As a lexical rule, it can be seen as a process in which the place of articulation features of vowels in unstressed syllables are removed from the lexical representations of words; subsequently, a default rule will fill in the relevant features of the schwa (cf. Kiparsky, 1995, p.642-47 for this interpretation of lexical diffusion). Simultaneously, vowel reduction is a postlexical rule applying to vowels in syllables without lexical stress, and a process of phonetic implementation for vowels (even those with lexical stress) that are not stressed in a particular utterance.

The alternation between full vowel and schwa is also visible in related pairs of words that differ in whether the relevant vowel is stressed or not; if the vowel is unstressed it can reduce, but also be pronounced as a full vowel:

(5.20) a p*e*rsóon 'person' pèrs*o*néel 'staff'
p*e*rcént 'procent' pèrc*e*ntáge 'id.'
p*a*stóor 'priest' pàst*o*ráal 'pastoral'
b profé*e*t 'prophet' pròfet*e*er 'to prophesy'
juwé*e*l 'juwel' jùw*e*lier 'jeweler'
gê*n*e 'embarrasment' g*e*nánt 'embarrassing'

The words in (5.20a) exhibit optional reduction, whereas in those in (5.20b) the vowel in italic can only be realized as schwa. That is,

the words in (5.20a) are subject to the postlexical rule of vowel reduction whereas the words in (5.20b) exhibit lexical diffusion effects. This implies that a morpheme like *juweel* will have two different lexical representations, /jyʊe:l/ when it is an independent word, and /jyʊəl/ when occuring in *juwelier*. This does not cause any computational problem since words are the units of storage, and thus the two allomorphs will automatically appear in the right context. The only problem that the language user has to solve here, is the recognition problem: how can both forms be recognized as forms of the same morpheme (a prerequisite for the semantic analysis)? But this is part and parcel of commanding a language since allomorphy that is not reducible to one underlying form is a widespread phenomenon, as we saw above (cf. also Booij, 1997a; 1997b; 1998).

Van Bergem, 1995 rightly qualifies this process of vowel reduction as a sound change in progress, which came into being due to interpretation by the native speaker of acoustic vowel reduction as a process of replacement of full vowel with schwa. It also exhibits lexical diffusion, since in some words the unstressed vowel can only be realized as a schwa, as we saw above. Furthermore, this kind of reduction is boosted by high frequency: in high frequency words unstressed vowels are reduced more easily and more frequently than in low frequency words. This is to be expected since vowel reduction reduces lexical contrasts, and thus impedes word recognition. High frequency, on the other hand, boosts recognition, and can thus compensate for the negative effects of vowel reduction.

The question then arises if the postlexical rule of optional vowel reduction in unstressed syllables is phonetically gradual, or should be interpreted as the replacement in lexical representations of the full vowel with schwa by means of a phonological rule, just as in the case of the lexical rule of vowel reduction. If the first position is taken, this may have the further implication that the degree of reduction of the vowel is encoded in lexical representation. This position is argued for in Bybee (to appear, a, b) for some other cases of reduction, and implies that details of the phonetic realization of phonemes are lexically specified. Can we say something about this on the basis of Dutch vowel reduction?

The data in Van Bergem, 1995, p.21 show that there is a positive correlation between frequency and acoustic parameters: in high frequency words the formant values for the unstressed vowel are farther away from the target values than in low frequency words. Moreover, this correlates with how native speakers perceive these vowels: "the average number of schwa responses increases when the spectral distance between the test vowel and its target increases" (Van Bergem, 1995, p.125). These results are explained if the growing distance between the acoustic parameters

of unstressed vowels in words of high frequency and those of the non-reduced correlates is lexically encoded: each time a vowel is reduced, its formant values move away from those of the unreduced vowel. This is the kind of explanation advocated in Bybee (to appear, a). The theoretical implication of this step is that lexical representations are not redundancy-free as far as phonetic details are concerned, a position also defended by Ohala and Ohala, 1995.

This position as to the lexical specification of vowel reduction effects is supported by the observation that data concerning optional vowel reduction can be obtained by means of introspection: native speakers of Dutch systematically know that certain words are more susceptible to vowel reduction than other. For instance, they know that the /i/ in *minuut* is susceptible to reduction, whereas the /i/ in *pilóot* 'pilot' is not. This suggests that such information is stored in memory.

The conclusion to be drawn is that phonological rules may be productive and automatic, and yet at least some of their outputs are lexically stored because the process exhibits lexical diffusion. In addition, it seems that phonetic details concerning the pronunciation of vowels can be stored, given the facts concerning the gradual erosion of unstressed vowels. Note, however, that this kind of stored information does not necessarily lead to a proliferation of distinct underlying forms (in the sense of 'bases for morphological operations') for a morpheme. This is a crucial difference between lexical and postlexical rules: it is only the effects of lexical rules that may lead to more than one underlying form for a particular morpheme.

4. Conclusions

In this chapter, we saw that the standard view in generative phonology of the balance between storage and computation has to be reconsidered: there is a wealth of evidence for the position that predictable information is stored in the lexicon. First, recent theoretical developments in phonology imply that the allomorphs of morphemes are stored in the lexicon to a much higher degree than previously assumed. Secondly, data concerning phonological change show that computable information concerning the phonetic realization of morphemes has nevertheless to be stored lexically. I also proposed that with respect to the relation between underlying form and phonetic form we should take a radical step: it is not the phonetic form that is computed by the speaker, but rather the underlying form. Like storage in general, storage of phonetic forms of words will speed up processing; it is only when we coin a new word that computation of the underlying form of the base word is necessary.

These conclusions do not refute the position that the human language faculty has a dual structure: a lexicon with stored representations and rules. The native speaker does need rules for the perception and production of novel forms. What, however, these conclusions do refute is the position that computation and storage of information with respect to the same process or regularity are mutually exclusive.

Acknowledgments

I would like to thank my colleagues Jaap van Marle, Piet van Reenen, and Leo Wetzels, and the anonymous referee for their comments on an earlier draft of this paper.

References

Anderson, S. (1974). *The organization of phonology.* New York etc.: Academic Press.

Baayen, H., Burani, C., and Schreuder, R. (1997). Effects of semantic markedness in the processing of regular nominal singulars and plurals in Italian. In Booij, G. and Van Marle, J., editors, *Yearbook of Morphology 1996*, pages 13–34. Dordrecht: Kluwer.

Bloomfield, L. (1933). *Language.* London: Allen & Unwin.

Booij, G. (1982). Fonetische en fonologische aspecten van klinkerreductie. *Spektator*, 11:295–301.

Booij, G. (1995). *The phonology of Dutch.* Oxford: Clarendon Press.

Booij, G. (1997a). Allomorphy and the autonomy of morphology. *Folia Linguistica*, 31:25–56.

Booij, G. (1997b). Autonomous morphology and paradigmatic relations. In Booij, G. and Van Marle, J., editors, *Yearbook of Morphology 1996*, pages 35–53. Dordrecht/Boston: Kluwer.

Booij, G. (1998). Prosodic output constraints in morphology. In Kehrein, W. and Wiese, R., editors, *Phonology and morphology of the Germanic languages*, pages 1–20. Tübingen: Niemeyer.

Booij, G. (1999). Lexical storage and regular processes. *Behavioural and Brain Sciences*, 22:1016.

Bybee, J. (to appear, a). Lexicalization of sound change and alternating environments. In Pierrehumbert, J. and Broe, M., editors, *Papers in Laboratory Phonology*, volume V. Cambridge: Cambridge University Press.

Bybee, J. (to appear, b). The phonology of the lexicon: evidence from lexical diffusion. In Barlow, M. and Kemmer, S., editors, *Usage-based models of language.*

Clahsen, H. (1999). Lexical entries and rules of language: a multidisciplinary study of German inflection. *Behavioural and Brain Sciences*, 22:991–1013.

Clements, G. N. and Keyser, S. J. (1983). *CV Phonology*. Cambridge MA: MIT Press.

Jackendoff, R. (1975). Semantic and morphological regularities in the lexicon. *Language*, 51:639–671.

Jackendoff, R. (1997). *The architecture of the language faculty*. Cambridge MA: MIT Press.

Janda, R. (1998). Comments on the paper by Perlmutter. In Lapointe, S., Brentari, D., and Farrell, P., editors, *Morphology and its relation to Syntax*, pages 339–359. Stanford: CSLI.

Kager, R. (1996). On affix allomorphy and syllable counting. In Kleinhenz, U., editor, *Interfaces in phonology*, pages 151–171. Berlin: Akademieverlag.

Kenstowicz, M. (1994). *Phonological theory*. Cambridge MA: Blackwell.

Kenstowicz, M. and Kisseberth, C. (1979). *Generative phonology*. New York: Academic Press.

Kiparsky, P. (1988). Phonological change. In Newmeyer, F., editor, *Linguistics, the Cambridge Survey*, volume 1, pages 363–415. Cambridge: Cambridge University Press.

Kiparsky, P. (1995). The phonological basis of sound change. In Goldsmith, J., editor, *The handbook of phonological theory*, pages 340–370. Cambridge MA: Blackwell.

Labov, W. (1981). Resolving the neo-grammarian hypothesis. *Language*, 57:267–309.

Labov, W. (1994). *Principles of linguistic change. Internal factors*. Oxford: Blackwell.

Lahiri, A. and Marslen-Wilson, W. (1992). Lexical processing and phonological representation. In Docherty, G. and Ladd, D. R., editors, *Papers in Laboratory Phonology II, Gesture, Segment, Prosody*, pages 229–254. Cambridge: Cambridge University Press.

Langacker, R. (1987). *Foundations of Cognitive Grammar. Vol 1. Theoretical Prerequisites*. Stanford Calif.: Stanford University Press.

Lapointe, S. G., Brentari, D. K., and Farrell, P. M., editors (1998). *Morphology and its relation to syntax*. Stanford: CSLI.

Leben, W. (1979). The phonological component as a parsing device. In Dinnsen, D., editor, *Current approaches to phonological theory*, pages 174–201. Bloomington and London: Indiana University Press.

Levelt, W. J. M. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition*, 42:1–22.

Mester, A. (1994). The quantitative trochee in Latin. *Natural Language and Linguistic Theory*, 12:1–61.

Ohala, J. and Ohala, M. (1995). Speech perception and lexical representation: the rule of vowel nasalization in Hindi and English. In Connell, B. and Arvaniti, A., editors, *Papers in laboratory phonology*, volume IV, pages 41–60. Cambridge: Cambridge University Press.

Ortmann, A. (1998). Consonant epenthesis: its distribution and phonological specification. In Kehrein, W. and Wiese, R., editors, *Phonology and morphology of the Germanic languages*, pages 51–76. Tübingen: Niemeyer.

Perlmutter, D. (1998). Interfaces: explanation of allomorphy and the architecture of grammars. In Lapointe, S., Brentari, D., and Farrell, P., editors, *Morphology and its relation to syntax*, pages 307–338. Stanford: CSLI.

Plag, I. (1998). Morphological haplology in a constraint-based morpho-phonology. In Kehrein, W. and Wiese, R., editors, *Phonology and morphology of the Germanic languages*, pages 199–215. Tübingen: Niemeyer.

Raffelsiefen, R. (1999). Phonological constraints in English word formation. In Booij, G. and Van Marle, J., editors, *Yearbook of morphology 1998*, pages 225–87. Dordrecht: Kluwer.

Trommelen, M. (1984). *The syllable in Dutch. With special reference to diminutive formation.* Dordrecht: Foris.

Van Bergem, D. (1995). *Acoustic and lexical vowel reduction.* PhD thesis, Univ. of Amsterdam.

Van Loey, A. (1964). *Schönfeld's historische grammatica van het Nederlands.* Zutphen: Thieme.

Van Loon, J. (1986). *Historische fonologie van het Nederlands.* Leuven/Amersfoort: Acco.

Wetzels, L. (1981). *Analogie et lexique. Le problème de l'opacité en phonologie generative.* PhD thesis, Catholic University Nijmegen.

Wetzels, L. (1984). Paradigm leveling in Latin and Old French: A critical view of rule inversion. In Baldi, P., editor, *Papers from the XIIth Linguistic Symposium on Romance Languages*, pages 579–599. Amsterdam: Benjamins.