Dutch inflection: The rules that prove the exception. *

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Abstract. This paper addresses the balance of storage and computation in the mental lexicon for fully regular and productive inflectional processes in Dutch. We present evidence that both regular inflected nouns and regular inflected verbs show clear and robust effects of storage, but that at the same time on-line parsing also plays a role. We argue that the balance of storage and computation cannot be predicted on the basis of economy of linguistic description. Instead, a range of cognitive and linguistic factors are crucial determinants.

Keywords: morphological processing, frequency effects, dual route modelling, inflection, regularity, economy of description, defaults

1. Introduction

This paper addresses the issue of the balance of storage and computation for regular inflected words in Dutch in language comprehension. Traditionally, this question has not been an issue in linguistics. Ever since Bloomfield (1933), the lexicon has been the repository of idiosyncracies. Listing in the lexicon is restricted to monomorphemic words and to complex words that are not predictable by rule, whether at the level of form or at the level of meaning. For linguistics as a descriptive discipline, this approach is justified, as the listing of complex words sharing features that can be predicted by rule implies the loss of generalizations.

In computational linguistics, practical considerations have led researchers to store the shorter complex words in their parsing programs in order to minimize the costs of having to analyze — on-line — such often highly ambiguous and frequent forms. In recent computational approaches such as data-oriented parsing (Bod, 1998) and lazy learning (Daelemans, Zavrel, Van der Sloot, & Van den Bosch, 1999), extensive storage of regular words and multi-word structures is used to optimize on-line performance. In these approaches, the data are the primary

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source of information, and no attempt is made to extract explicitly from the data rules for analysing unseen constructions.

In psycholinguistics, the complete range of possible trade-offs between storage and computation has found its defenders. Butterworth (1983) was the first to formulate the hypothesis that complex words in a language such as English are extensively stored in the mental lexicon, and that parsing is a back-up analogical procedure used only for the rare instances in which novel forms are encountered. Connectionist models of the kind advocated by Seidenberg (1987) are implementations of this position using a framework in which distributed data storage takes place without any role for explicit morphological rules. Effects of morphological structure observed in on-line processing experiments are, in this approach, an epiphenomenon of statistical regularities between input and output patterns. The opposite extreme has been defended by Pinker (1991), Marcus, Brinkman, Clahsen, Wiese, & Pinker (1995), and Clahsen, Eisenbeiss, & Sonnenstuhl-Henning (1997). Their approach assumes that Bloomfield's position is an adequate characterization of the balance of storage and computation in human language processing. An intermediate position has led to the formulation of a parallel dual route model (Schreuder & Baayen, 1995), in which rules and memory-based retrieval operate in parallel.

The aim of the present chapter is to address the question of the balance of storage and computation for regular inflected words. Pinker, Marcus, Clahsen, and also Jaeger, Lockwood, Kemmerer, Van Valin, & Murphy (1996) have argued that regular and irregular inflected complex words are processed differently by the brain, irregulars being handled by memory-based retrieval, and regulars being handled by rule (but see Plunkett & Juola, 1999, and Seidenberg & Hoeffner, 1998, for alternative interpretations of the data). One of the arguments used by Pinker and Clahsen concerns the occurrence of frequency effects for complex words, which they argue to be restricted to irregular complex words.

There are two distinguishable token frequency effects. The Surface Frequency Effect concerns the finding that the frequency of occurrence of a complex word such as *walks* can be an important predictor of response latencies in a variety of word recognition tasks. The Base Frequency Effect concerns the observation that the frequency of the lexeme *walk*, i.e., the summed token frequency of *walk* and all its inflectional variants, can also be an important predictor of such response latencies. The effects of Surface Frequency and Base Frequency are independent, as shown by Taft (1979) and Burani, Salmaso, and Caramazza (1984) for English and Italian inflected words. The existence of a Surface Frequency Effect is generally interpreted as evidence for storage of the inflected word as a whole at some level of representation.

The existence of a Base Frequency Effect indicates that at some point during lexical access the base word itself has been accessed. The claim advanced by Pinker and Clahsen is that for regular inflected words only Base Frequency Effects should be observed and no Surface Frequency Effects.

Our research, however, has revealed very reliable Surface Frequency Effects for regular inflected words. For Dutch, Italian, and English, regular noun plurals show substantial Surface Frequency Effects (Baayen, Dijkstra, & Schreuder, 1997; Baayen, Burani, & Schreuder, 1997; Sereno & Jongman, 1997; and Allegre & Gordon, 1999). In Finnish, such an effect has been reported for regular partitive noun plurals, even though Finnish is a language with a very rich morphology (Bertram, Laine, Baayen, Schreuder, & Hyönä, 1999). In Dutch, furthermore, fully regular comparatives have been found to show Surface Frequency Effects (Bertram, Schreuder, & Baayen, 1999). These results call into question the idea that the economy of linguistic description, which requires maximization of rule-based description and minimization of list-based description, can be mapped directly onto the domain of lexical processing in the mental lexicon. In the cognitive domain, it is not a priori self-evident that the costs of processing by rule are less than the costs of storage (Frauenfelder & Schreuder, 1992). The storage capacity of the human brain is enormous (Landauer, 1986), and it is well known from various cognitive domains (e.g., hand reaches, Rosenbaum, Vaughan, Barness, & Jorgensen, 1992, and arithmetic, Rickard, Healy, & Bourne, 1994) that storage may take over when computations become complex and time-consuming. In the domain of morphological processing, storage might likewise be a useful mechanism complementing rule-based access.

Moreover, from a more general linguistic point of view, storage for regular noun plurals as observed by Baayen, Dijkstra, & Schreuder (1997) is not that surprising either. Tiersma (1982) has pointed out that high-frequency plural forms are what he called locally unmarked. Normally, plurals are formally and semantically marked with respect to their singulars, as in the case of *nose* versus *noses*. On the other hand, plurals that are much more frequently used than their corresponding singulars tend to be semantically unmarked. For instance, *eyes* and *feet* are unmarked in the sense that they represent the default occurence of the objects they refer to. Tiersma shows that locally unmarked plural nouns serve as attractors in language change, which implies that such nouns must have been stored in the mental lexicon. Cross-linguistically, it is precisely the locally unmarked plural forms that emerge as simplex forms in languages such as Bari (Eastern Nilotic), which uses a singulative suffix to derive the singular form of a monomorphemic semantic plural noun (e.g., *kuru*, 'worms', *kuru-töt*, 'worm', Dimmendaal, 1987).

Clahsen et al. (1997), however, have suggested another reason why effects of storage might have been observed for Dutch noun plurals, namely, their supposed irregularity. Clahsen and his colleagues argue that a more subtle notion of regularity is called for than the one used in traditional grammars (Clahsen et al. 1997:208). In order to ascertain whether the plural noun suffixes of Dutch fall into what they call the regular cluster, the properties of Dutch noun plurals would have to be checked against a reference list of linguistic criteria for regularity as proposed by Marcus et al. (1995:197). In this approach, the traditional notion of regularity has been replaced by the notion of default. Default forms are said to be free of morphological restrictions and lexical governance, they are claimed to attract members of non-default classes in historical change. Loan words and marginal forms such as acronyms and abbreviations are also analyzed to fall into default classes.

Other scholars have likewise questioned the regularity of the Dutch plural suffixes (Gordon, 1985; Pinker and Prince, 1991), on the basis of the occurrence of Dutch noun plurals in compounds, and on the basis of the plurals being rival affixes.

In what follows, we will examine this important alternative explanation for why storage effects in lexical processing might arise: irregularity. If it is indeed the case that some form of irregularity is the driving force behind any storage in the mental lexicon, then irregularity would overrule more general cognitive considerations concerning the balance of storage and computation in general. Before assigning primacy to irregularity as a the driving force behind lexical storage, we should consider in detail whether it is linguistically justified to describe Dutch noun pluralization as in some sense irregular. In section 2, we therefore examine noun plural formation in Dutch with respect to the notion of default developed by Marcus et al. (1995). We will show that the system of noun pluralization is regular, and that native speakers of Dutch coin new noun plurals exactly as predicted. In section 3, we will proceed to show that Surface Frequency Effects may also appear for fully regular verbal inflections which can only be described as default suffixes. In the General Discussion, we will trace some of the theoretical consequences of our findings.

2. Dutch noun plurals

In this section, we first present an outline of the rules governing the distribution of the plural suffixes in Dutch. We then proceed to show that speakers of Dutch apply these rules consistently without problems to phonotactically legal pseudo words, which illustrates that pluralization is indeed rule-governed.

2.1. The rules

There are three plural suffixes in Dutch: *-en*, *-s*, and *-eren*. The latter suffix occurs only in 15 nouns, and need not concern us here.

There are five factors that determine the distribution of *-en* and *-s*, both of which are fully productive. The main factor is the phonological structure of the base word: *-s* appears after unstressed syllables, and *-en* appears after stressed syllables. From the phonological point of view, *-s* and *-en* are in complementary distribution, and can be considered synchronically as suppletive forms. There are some further phonological restrictions: Words ending in a full stressed vowel often select *-s* rather than *-en*, which may be due to avoid a sequence of two non-homorganic vowels: *pa's*, 'dads'. Furthermore, if a word already ends in an *-s*, the appropriate suffix is *-en*: *cactussen.*

A second important factor is morphological in nature. Some suffixes always require *-en*, e.g., *-ing*, '-ing', other suffixes only take *-s*, e.g., the diminutive suffix *-tje*, while yet others allow both, e.g., *-isme*, '-ism'.

Third, loan words select *-s*, e.g., *stations, trams, jeeps.*

Fourth, the *-s* tends to be selected for persons as opposed to things, especially in the case of homonyms: *portiers*, 'doorkeepers' versus *portieren*, 'car doors'.

Fifth, both suffixes are possible for nouns ending in a schwa (*kade*: *kades, kaden*, 'quay'), more formal registers prefer the suffix *-en.*

The existence of choice for words ending in a schwa can be understood in terms of the general preference for disyllabic trochees in Germanic (see Booij, 1998, for an account in terms of optimality theory). Both *kades* and *kaden* as plural forms of *kade* satisfy this rhythmic constraint (van Haeringen, 1947) of Dutch. There are words for which the first factor (the rhythmic principle) clashes with the fourth factor, which specifies *-s* as the choice for person names. In such cases, both suffixes can be used: *leraar*, 'teacher', has as plural forms both *leraars* (by factor 4) and *leraren* (by factor 1).

Finally, there are also some exceptions to these rules, such as *wonder*, 'miracle', which has as its plural *wonderen* instead of *wonders.* In a linguistic description, these exceptions can be handled by listing, just as the irregular plurals in *-eren* must be listed.

In sum, *-en* and *-s* are typical rival suffixes in the sense of Van Marle (1986). Each suffix has its own specific input domain, defined on several dimensions: phonology, morphology, semantics, and register. On each dimension, there is a regular devision of labor between the two suffixes, although the overall outcome of their affixal rivalry may lead to both suffixes being acceptable for particular subdomains.

Having outlined the system of Dutch plural formation, we now consider whether the notion of default in the sense of Marcus et al. (1995) and Clahsen et al. (1997) can be applied to the complementary distribution of Dutch noun plurals. The study of Marcus et al. (1995) contrasts irregular inflection with regular inflection for German. This study claims that the German *-s* plural is the default, that because it is the default it is processed by rule, while all other German noun plurals fall outside the regularity cluster and are processed by means of retrieval from memory. The use of the term default for a particular morphological operation that can be used when other morphological operations with idiosyncratic input domains do not apply has a long history that goes back to Panini, and that has been formalized in morphological theory as the elsewhere condition (Kiparsky, 1973, 1982). Marcus et al. (1995) and Clahsen et al. (1997) use the notion of default to denote the elsewhere condition, and by taking the default to be prototypically regular, non-default operations now fall outside the regularity complex and become in some sense irregular. This amounts to the idea that whenever more than one affix is available for the realization of an inflectional function, only one of these affixes can be truly regular.

Is this notion of default applicable to the Dutch noun plurals? According to Marcus et al. (1995), a default suffix is marked by a wide range of different but converging properties:

First, the default affix is used for words that do not have an entry in the mental lexicon. By this criterion, however, both *-en* and *-s* are defaults. Nonwords such as *snarp* and *krilgem* pluralize as *snarpen* and *krilgems* by factor 1.

Second, the default affix is selected for expressing a more specialized meaning than carried by the irregular form, e.g, hanged *for a form of execution instead of* hung. According to this criterion, the *-s* would be the default, as it intrudes into the phonological input domain of *-en* to denote persons (*portiers*, 'door keepers', compare *portieren*, 'car doors').

Third, the default is the affix to attach to non-canonical roots: onomatopeia, quotations, surnames, acronyms, unassimilated borrowings. As we have seen, *-s* is used in Dutch for unassimilated borrowings, but here we should keep in mind that many loan words may be borrowed together with their plural form, which, in the case of borrowings from English or French, already may have a plural in *-s*. Moreover, the *-en* is not available as a noun plural for loan words, because it functions as a verbal ending both for indigenous verbs and for loan words: the conversion verb *trammen* means 'to go by tram' and *computeren* means 'to use a computer', while *trams* and *computers* are the plurals of *tram* and *computer*. Hence, the force of the argument that *-s* would be the default because it attaches to loan words is unclear.

Both *-s* and *-en* attach to surnames. When proper names are pluralized, the phonological form of the base determines the choice of suffix: *de Neit-en*, *de Levelt-s*. Often, the rhythmic principle applies (e.g., *PABOs*, *HATten*), but equally often both plural suffixes can be used. This criterion does not allow us to select either affix as the default.

Fourth, the default suffix attaches to words that normally do not undergo inflection. In Dutch, the rhythmic principle again determines the choice: *of-en*, 'ifs', *maar-en*, 'buts', *buitens*, 'outs', and *binnens*, 'ins'. This suggests again that there is no simple default in Dutch.

Fifth, exocentric formations require the default suffix. Again, the rhythmic principle determines the choice between *-s* and *-en*, and not default status. For instance, the noun *schip* has the irregular plural *schepen*. However, the plural of *schip* when mentioned meta-linguistically rather than used is *schippen*, not *schips*. When a word such as *lepel*, 'spoon', is to be pluralized when mentioned instead of used, its plural will not differ from the standard plural, *lepels*. Similarly, we have two *Mercedes-CLen* and three *Citroen-Saxo's*.

Sixth, under memory failure, the default affix is used. Although we have no concrete data on speech errors for Dutch noun plurals, our intuition is that the rhythmic principle is so strong that for monomorphemic words errors will be few and evenly balanced between *-en* and *-s*.

Summing up, there are two pieces of evidence that suggest that *-s* might be the default in Dutch, namely, its use for loan words, and its use to denote persons, but these two criteria are not compelling, and they are counterbalanced by massive evidence that *-en* shares all other default properties with *-s*. We conclude that the Dutch plural system does not have a clear default in the sense of Marcus et al. (1995) or Clahsen et al. (1997). In fact, the six clusters of criteria provide an elegant series of lithmus tests for productive regularity once 'default' is replaced by 'regular'. Both *-en* and *-s* are regular fully productive suffixes in this sense.

However, Pinker and Prince (1991) argue that the complementary distribution of *-en* and *-s* in Dutch indicates that these suffixes would not have unrestricted productivity. It is unclear to us in what sense this would call the regularity of the Dutch plural system into question. The complementary distribution of rival affixes has indeed been interpreted as qualitatively restricting productivity (Schultink, 1961; Booij, 1977; Van Marle, 1985), but quantitatively these qualitative restrictions have little or no weight. For instance, the verb-forming prefix *ver-* attaches to verbs (*verslaan*, 'to beat', from *slaan*, 'to hit'), to nouns (*verhuis*, 'to move house', from *huis*, 'house'), and to adjectives (*vergroot*, 'to magnify', from *groot*, 'big') and occurs with some 950 formations in the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995). In terms of its input domain, the suffix *-heid* ('-ness' in English) is far more restricted in that it attaches only to adjectives. Nevertheless, 3017 formations in *-heid* are attested in CELEX. Even though *ver-* has fewer restrictions as to word category than *-heid*, which would predict that *ver-* should be more productive than *-heid*, the reverse holds: *-heid* is more productive than *ver-*. Clearly, the number of qualitative restrictions has little to say about how often an affix is used or might be used potentially in the language (see Baayen 1992; Baayen and Renouf, 1996, for detailed discussion).

Therefore, the simple fact that *-en* and *-s* are in regular complementary distribution cannot by itself constitute evidence for or against the regularity or default status of *-s* or *-en*. In fact, the traditional notion of being in complementary distribution is perpendicular to the notion of regularity. The complementary distribution of the English plural suffix *-s/-z/-iz* has, as far as we know, never been proposed as evidence that this suffix and its phonological alternants should be classified as irregular or outside a regularity complex.

In the light of these considerations, we conclude that Dutch noun plurals in *-en* and *-s* are fully regular. Hence, we maintain that the experimental evidence reported in Baayen, Dijkstra, and Schreuder (1997) shows that fully regular inflected words can be stored in the mental lexicon.

2.2. The rules applied

In order to make sure that the rules governing the distribution of the plural suffixes *-s* and *-en* described above are truly predictive, we carried out a simple production experiment in which participants had to build plural forms for pseudo word singulars.

Experiment 1

Method

Participants. 49 participants, mostly undergraduates at Nijmegen University, were paid to take part in this experiment. All were native speakers of Dutch.

Materials. We constructed 80 pseudo words, none of which violated the phonotactic rules of Dutch. In order to test the rhythmic principle, 10 of these were stressed one-syllabic pseudo words (e.g., *dréip*) whose plural suffix is predicted to be *-en*, and 10 were two-syllabic pseudo words with an unstressed final syllable (e.g., *wórkel*) whose plural suffix is predicted to be *-s*. Ten pseudo words were two-syllabic words ending in schwa whose plural, according to the rhythmic principle, can be built with either *-(e)n* or *-s*. Ten two-syllabic pseudo words with an unstressed final syllable ended with the consonant *s*. These words are predicted to take *-en* as plural suffix. Ten words ended in a full stressed vowel, 5 ending in *-ee* (e.g., *stree*), and 5 ending in *-a* (e.g., *kna*). The rhythmic principle predicts the plural suffix *-en*, but the suffix *-s* is also possible in order to avoid a sequence of two non-homorganic vowels. To test the morphological factor we created 10 pseudo words for three kinds of derived words: *-ing* derivations (e.g., *bestroet-ing*) whose plural suffix should be *-en*, *-tje* derivations (e.g., *kloer-tje*) whose plural suffix should be *-s*, and *-isme* derivations (e.g., *kad-isme*) whose plural suffix can be either *-en* or *-s* according to the rhythmic principle. The materials are listed in Appendix A. Word stress was not indicated in the test materials, as all words were patterned on the germanic word-initial stress pattern, and as the only set with real orthographic ambiguity (the set with two syllable pseudo words ending in a final *s*) are, because of the final s, words which must pluralize in *-en* independent of the stress pattern assigned.

*Procedure.*The experiment was a paper and pencil task. Participants were asked to write down the plural forms for a list of pseudo words. The experiment lasted approximately 5 minutes.

Results and Discussion

In our analysis, we counted only responses built with the plural suffixes *-en* or *-s*, not including 72 (1.8%) responses which were mostly constructed with latinate plural suffixes, which we regarded as errors. (Such latinate plurals were produced for pseudo words ending in, e.g., *us*, a nominative singular ending in Latin.) Table 1 shows the number of responses for the nine experimental conditions.

In the experimental conditions for which the plural suffix *-en* was expected, participants used this suffix for 96.3% up to 100% of the pseudo singulars to create a plural noun. When the plural suffix *-s* was expected, 97.9% up to 99.6% of the plural forms were indeed built with *-s*. In the case where both suffixes are possible, the preference for one particular suffix was never greater than 81.1%. The suffix *-en* was used more often when the pseudo word ended in a schwa (70.4%), the full vowel *e* (70.2%), or in the suffix *-isme* (75.1%). When the pseudo word ended in *a*, participants preferred an *-s* (81.1%).

Table I. Experiment 1: Number and percentage of pseudo word plurals in *-s* and *-en*.

condition	expected suffix	S	%S	EN	%EN
dréip	*-en*	18	3.7	469	96.3
wórkel	*-s*	469	97.9	10	2.1
bástuS	*-en*	0	0	445	100
bestroet-ing	*-en*	5	1.0	484	99.0
kloer-tje	*-s*	488	99.6	2	0.4
kna	both	198	81.1	46	18.9
stree	both	73	29.8	172	70.2
stape	both	144	29.6	343	70.4
kad-isme	both	120	24.9	362	75.1

For the first 5 conditions in Table 1, the choice of plural suffix is deterministic according to the rules. This is reflected in the behavior of our participants, who selected the predicted suffix for 2355/2390 = 98.5% of the pseudo singulars. For the remaining four vowel-final conditions, both plural endings are possible in principle, and again this is what we find in our data. We observe that *-s* appears to be the preferred choice (81%) for words in *a*, while words in *-e* and schwa as well as words in *-isme* select *-en* for roughly 70% of the pseudo words. Note that variability of suffix choice for the subsets of pseudo words labelled 'both' in Table 1, for which the rules of plural formation in Dutch are non-deterministic, is of another order of magnitude (*-s* is selected in 30% up to 80% of the pseudo words) than the variability that is not predicted by the rules (100% - 98.5% = 1.5% with the incorrect suffix, calculated for the first 5 sets in Table 1 jointly). Also note that *-s* is the dominant choice for one of the non-deterministic subdomains (final *a*), while *-en* is the dominant choice for the other non-deterministic subdomains. This shows that it is impossible to designate *-en* or *-s* as default on the basis of overall dominance in the non-deterministic subdomains.

In order to ascertain whether the observed differences are reliable, we used a classification and regression tree analysis (Breiman, Friedman, Olshen, & Stone, 1984) to predict the choice of plural suffix from the independent variables Rhythmic Principle (stressed or unstressed final syllable), Morphology (*-ing, -tje, -isme* or monomorphemic), and

Phonology (final *a, e*, final schwa, final s, or other). Using 10-fold cross-validation and cost-complexity pruning (Venables & Ripley, 1994), we obtained a classification tree which identified the sets separated by horizontal lines in Table 1 as statistically reliable distinct subclasses.

The fact that participants are able to form plural forms for pseudo singulars according to the rules for plural formation in Dutch confirms that the system of plural formation in Dutch is truly fully regular and productive.

In the next section we will present experimental evidence that not only fully regular noun plurals are stored, as shown by Baayen, Dijkstra, & Schreuder (1997), but that also fully regular inflected verbs which have no rival 'suppletive' affix in the language reveal substantial effects of storage. At the same time, we will argue that the very same data also shed light on the circumstances under which the parsing route will contribute effectively to lexical access.

3. Dutch verbal inflections

We have seen that there are no compelling linguistic reasons to assume that the Dutch noun plural suffixes are in some sense irregular. In fact, it has proved to be very difficult to designate either suffix as being or not being a default. In this section we report three visual lexical decision experiments concerning verbal morphological inflectional processes for which the question of default status does not arise, simply because there are no rival morphological processes in the language realizing the same semantic and syntactic functions. Is it possible to observe Surface Frequency Effects for inflected words of this kind?

The first experiment investigates the perfect participle, which in Dutch is formed by the circumfix *ge- -D*, where /D/ represents an alveolar stop that is realized either as a /d/ or as a /t/ depending on the phonological context. In our experiment, we have used only words that are written in the orthography with a final *d*: *gewandeld*, 'walked'. We have used a simple factorial design in which two sets of words are compared: words with on average a high Surface Frequency, and words with on average a low Surface Frequency. The two sets of words were matched with respect to Base Frequency and Family Size, the number of derived words and compounds in which the base word appears as a constituent (see Schreuder & Baayen, 1997; Bertram, Baayen, & Schreuder, 1999; De Jong, Schreuder, & Baayen, 1999). If Surface Frequency plays a role during lexical processing, then a difference in the mean reaction times for the two groups should be observed, with shorter response latencies for the words with the higher Surface Frequencies, which would indicate that these regular participles are stored in the mental lexicon.

The second experiment applies the same experimental design to the plural past tense suffix -*Den*, using only words in which the /D/ is realized orthographically and phonologically as -*d*: *wandelden*, 'we/you/they walked'. The third experiment similarly studies the present participle suffix -*end*, as in *wandelend*, 'walking'. None of these experiments contained any irregular complex word whatsoever.

Experiment 2

Method

Participants. 25 participants, mostly undergraduates at Nijmegen University, were paid to take part in this experiment. All were native speakers of Dutch.

Materials. We selected 60 regular perfect participles with the circumfix *ge- -d* (e.g., *gegrijnsd*, 'grinned') from the CELEX lexical database, which is based on a corpus of 42 million wordforms. Thirty of these participles had a high Surface Frequency with an average of 18.34 (range 4.52–70.24, $\hat{s}$ 15.03), and 30 had a low Surface Frequency with an average of 0.94 (range 0.00–12.40, $\hat{s}$ 2.52) per million. The two sets were matched for Base Frequency (high: mean 118.44, range 9.76–430.88, $\hat{s}$ 118.18; low: mean 118.23, range 10.36–430.69, $\hat{s}$ 116.60), Family Size (high: mean 51.8, range 1–243, $\hat{s}$ 55.3; low: mean 50.9, range 3–282, $\hat{s}$ 57.7), and for mean length in letters (high: 7.9, low: 7.7). Note that matching for base frequency implies implicitly that other variables correlating with base frequency, such as number of senses, concreteness, and age of acquisition, are also controlled for between the high and low Surface Frequency groups. We added 38 monomorphemic words (mostly verbs) and 76 inflected verbs in the third person singular. Each word was paired with a pseudo word with the same morphological structure which did not violate the phonotactic rules of Dutch. The experiment was preceeded by 32 practice trials. There was a short pause after the practice session, and once during the experiment. In total, the experiment lasted about 20 minutes. The experimental materials are listed in Appendix B.

Procedure.

Participants were tested in noise-proof experimental rooms. They were asked to decide as quickly and accurately as possible whether a letter string appearing on the computer screen was a real Dutch word. Each stimulus was preceeded by a fixation mark in the middle of the screen for 50 ms. After 500 ms, the stimulus appeared at the same position. Stimuli were presented on Nec Multisync color Monitors in white lowercase 36 point Helvetica letters on a dark background and they remained on the screen for 1500 ms. The maximum time span allowed for response was 2000 ms from stimulus onset.

Results and Discussion

The participants performed the experiment with an error rate less than 13%. Table 3 lists mean reaction times and mean error scores for the two experimental conditions. The participles with a high Surface Frequency elicited reliably shorter response latencies ($t1(24) = -12.00, p = 0.00; t2(58) = -6.74, p = 0.00$), and less erroneous responses ($t1(24) = -7.25, p = 0.00; t2(58) = -4.97, p = 0.00$) than those with a low Surface Frequency. Clearly, this experiment shows that in Dutch regular participles can be stored in the mental lexicon.

Base Frequency and Surface Frequency are correlated variables in our materials. Pooling the words of the high and low Surface Frequency sets, we observe that the Pearson correlation between Base Frequency and Surface Frequency equals $r = 0.246, t(58) = 1.93, p = 0.03$ (one-tailed test). Given the strong negative correlation of Surface Frequency with the reaction times ($r = -0.730; t(58) = -8.14, p = 0.00$), one would expect a negative correlation of Base Frequency with reaction time as well (see, e.g., Bertram, Schreuder, & Baayen, 1999). However, there is no such correlation for Base Frequency ($r = -0.000; t < 1$). We therefore inspected the partial correlation of Base Frequency and reaction time, partialling out the correlation of reaction time with Surface Frequency. This partial correlation turned out to be positive and, surprisingly, reliable: $r = 0.27(t(57) = 2.12, p = 0.04)$ (two-tailed test). This positive correlation shows that response latencies to the perfect participle become longer when its base is more frequent.

How can we explain this unexpected result? Two possible explanations suggest themselves. First, we may be observing an effect of competition between the access representation of the base word *wandel* (a free form in Dutch) and that of the participle, *gewandeld*. Access representations are modality specific representations of the form of words, either their orthographic shape or their phonological form. In many current models of word recognition, access representations enter into a process of competition for recognition. In this competition process, access representations that are similar to each other and to the target inhibit each other. Thus, the competition process is a selection mechanisms for weeding out irrelevant but similar forms (see, e.g., Grainger & Jacobs, 1996). In this framework, higher-frequency base words might lead to more severe competition between the access representations of *wandel* and *gewandeld*, resulting in a positive correlation between Base Frequency and reaction time. This explanation runs into the problem, however, that under strict lexical competition, i.e., competition in which there is only one winning lexical candidate, one would expect symmetrical effects. If anything, one would expect the lower-frequency full-form to suffer more from the competition than the higher-frequency base, instead of the observed reverse. In the model for morphological segmentation developed by Baayen, Schreuder, & Sproat (1999), Baayen & Schreuder (1999a), and Baayen & Schreuder (1999b), however, there is no substantial competition between base and full form because the two routes work together rather than against each other. In this parallel dual route model, the observed positive correlation of Base Frequency and reaction time cannot be explained at the access level.

A second explanation locates the effect at a deeper, central level than that of the form-based access representations. The central level is the level where semantic and syntactic representations are activated, the level also at which alternative parses have to be weighted. In our parallel dual route model, access representations of affixes provide access to their syntactic and semantic properties before base words and full forms, due to their very high frequencies of use. (For evidence of this early availability of affixes in visual word recognition, see Bertram, Baayen, and Schreuder, 1999, and De Jong, Schreuder, and Baayen, 1999.) Likewise, base words often become available before full-form representations, again due to their higher frequency. A full segmentation of the input, e.g., *ge-wandel-d*, may therefore become available for central processing before the full form itself. This complete segmentation, however, contains a sub-parse that is incompatible with the correct parse: *ge-wandel* is an iterative action noun formed by prefixing the category-changing prefix *ge-*. Possibly, the incongruity of the sub-parse *ge-wandel* with the correct parse *ge-wandel-d* causes uncertainty at the central level of lexical processing that slows down responses based on the parsing route: More frequent base words will become available more quickly, leading to an earlier onset of uncertainty, and hence to longer response latencies and a positive correlation of Base Frequency with reaction time.

This second explanation receives further support from a more detailed analysis of the data, as not all participles have a corresponding form with *ge-*. In contrast to the pair *ge-wandel* and *ge-wandel-d*, participles such as *gedoemd* ('doomed') and *gestoeld* ('based on') do not have parallel forms with *ge-*. Interestingly, the subset of items for which a parallel form with *ge-* exists or is an easily interpretable possible form reveal a reliable positive partial correlation of Base Frequency and response latency ($r = 0.33, t(32) = 1.96, p = 0.03$, one-tailed test), while the corresponding partial correlation for the remaining items is

Table II. Mean response latencies and error proportions for the regular perfect participles of Experiment 2 (means by participants).

		RT	$\hat{s}$ RT	Error	$\hat{s}$ Error
Perfect participles	High Surface Frequency	594	79.88	0.04	0.05
	Low Surface Frequency	702	95.38	0.19	0.14

not reliable ($r = 0.15, t(22) = 0.73, p = 0.24$, one-tailed test). This confirms the hypothesis that the existence of a parallel form with *ge-*, or the plausibility of such a form, slows down response latencies in visual lexical decision.

Summing up, we have observed a 100 ms effect of Surface Frequency for a suffix that has no suppletive rival affix and that must be considered to be a default in the sense of Marcus et al. (1995). This shows unambiguously that Surface Frequency Effects cannot be used as a lithmus test for (ir)regularity. Interestingly, the very same data suggest that parsing is also going on for our experimental materials. The parsing route runs into problems, however, possibly at the access level, but more likely at a more central level of processing.

The present strong effect of storage for Dutch participles contrasts with results reported by Baayen, Dijkstra, and Schreuder (1997) for inflected past tense plural verbs with the suffix *-en* in Dutch and by Bertram, Schreuder, and Baayen (1999) for the singular past tense suffix *-te* in Dutch. Both studies report the complete absence of an effect of Surface Frequency. In fact, these authors hypothesize that while inherently inflected words may be stored (e.g., noun plurals), contextually inflected words such as person and number agreement marking on verbs are not stored (see Booij, 1993, for the distinction between contextual and inherent inflection). The present effect of Surface Frequency for our Experiment 2 may therefore have two sources. On the one hand, it may arise due to the parsing problem mentioned above. On the other hand, it may arise from the kind of word formation involved. Perfect participles are not prototypical inflected forms, as they often are used as adjectives and may acquire various idiosyncratic shades of meaning (e.g., *gezien* 'seen', has the additional meanings of being 'welcomed' and 'honored'). When we allow ourselves to assume that the perfect participle instantiates inherent inflection, the inconsistency with earlier results is resolved.

Returning to the question of the usefulness of the notion default, it might be argued that the notion of default comes into play primarily for the most prototypical kinds of inflection, i.e., contextual inflection, more than for less prototypical inflection such as the perfect participle. The next experiment therefore considers the plural past tense suffix *-den* as in *wandel-den*, ‘we, you, they walked’, which realizes not only tense (inherent inflection) but also number marking (contextual inflection).

Experiment 3

Participants. 28 participants, mostly undergraduates at Nijmegen University, were paid to take part in this experiment. All were native speakers of Dutch.

Materials. We selected 44 inflected past tense plural verbs with the suffix *-den* from the CELEX lexical database (e.g., *wandelden*, 'walked'). Twenty-two of these verbs had a high Surface Frequency with an average of 10.09 (range 0.55–38.29, $\hat{s}$ 9.99), and 22 had a low Surface Frequency of 0.30 (range 0.05–1.33, $\hat{s}$ 0.37). We matched the two sets of verbs with respect to Base Frequency (high: mean 156.24, range 3.12–863.24, $\hat{s}$ 223.96; low: mean 157.08, range 2.98–829.83, $\hat{s}$ 222.86), Family Size (high: mean 42.5, range 2–255, $\hat{s}$ 59.4; low: mean 38.6, range 2–309, $\hat{s}$ 67.7), and mean length in letters (high: 7.5, low: 8.0). We added 50 present participles with the equally regular inflectional suffix *-end*, serving as a separate experiment to be discussed below, and 90 inflected verbs in the third person singular. Each word was paired with a pseudo word with the same morphological structure which did not violate the phonotactic rules of Dutch. The experiment was preceeded by 30 practice trials. There was a short pause after the practice session, and once during the experiment. In total, the experiment lasted about 20 minutes. The materials are listed in Appendix C.

Procedure. The procedure was identical to that of Experiment 2.

Results and Discussion

One participant performed the experiment with an error rate of more than 15%, and was excluded from further analyses. Table 3 lists mean reaction times and mean error scores for the two experimental conditions. The verbs with a high Surface Frequency elicited reliably shorter response latencies ($t1(26) = -11.21, p = 0.00; t2(42) = -4.57, p = 0.00$), and less erroneous responses ($t1(26) = -4.83, p = 0.00; t2(42) = -2.71, p = 0.01$), than those with a low Surface Frequency.

Even though *-den* is more contextual in nature than the perfect participle, and even though it is a default suffix in the absence of a suppletive rival affix, we observe a substantial effect of Surface Frequency that is also supported by a post-hoc correlation analysis ($r = -0.67, t(42) = -5.83, p = 0.00$).

Table III. Mean response latencies and error proportions for the plural past tense inflections of Experiment 2 (means by participants).

		RT	$\hat{s}$ RT	Error	$\hat{s}$ Error
Past plural inflections	High Surface Frequency	586	59.8	0.07	0.06
	Low Surface Frequency	680	72.3	0.18	0.10

Bertram, Schreuder, and Baayen (1999) did not observe an effect of Surface Frequency for the singular past tense suffix *-te*. They show that derivational affixes reveal very reliable effects of Surface Frequency for the same range of Surface Frequencies where *-te* reveals only an effect of Base Frequency. Their data show that Surface Frequency Effects arise more easily with derived words than with contextually inflected words. However, the frequency contrast in their Experiment 1 was much smaller (5.3 versus 1.4 per million) than the contrast in the present experiment (10.1 versus 0.3 per million). The present experiment shows that, surprisingly, Surface Frequency Effects may even emerge for contextual inflection when the frequency contrast becomes large enough, even though *-den* is a suffix that is not in complementary distribution with other suffixes. For a similar recent finding for the inflectional suffix for the third person singular in the present tense paradigm, see Schreuder, De Jong, Krott, & Baayen (1999).

In the present experiment, Base Frequency revealed a reliable correlation with reaction time in the expected direction ($r = -0.31, t(42) = -2.09, p = 0.04$). However, as Surface Frequency and Base Frequency are strongly correlated for our materials ($r = 0.40, t(42) = 2.79, p = 0.008$), we also ran a partial correlation analysis of Base Frequency and reaction time, partialling out the correlation of Surface Frequency and reaction time. This partial correlation turned out not to be reliable ($r = -0.06, t < 1$). The present experiment, therefore, does not provide evidence for an independent contribution of Base Frequency. At the same time, it is not the case that a high Base Frequency leads to longer response latencies as observed in Experiment 2. This is what one would expect, as there is no parsing conflict for verbs ending in *-den*. Even when *den* is analyzed as a sequency of two morphemes, the past tense marker *-de* and the plural marker *-(e)n*, the two subparses *wandelde* and *wandelden* are not in conflict with respect to the word category of the input as is the case for the perfect participle (verbal for *gewandeld* and nominal for *gewandel*).

Our last experiment considers the Dutch present participle, which is formed by suffixation of *-end* (*wandelend*, 'walking'). The present participle is fully regular and productive, it is again a suffix without a suppletive rival suffix, and hence a default. However, it is also a form that is not often used in informal registers. It might be the case that, due to its lower frequency of use, the Surface Frequency Effect may be reduced or even absent for this suffix. Conversely, we expect the parsing route to play a more effective role for these lower-frequency inflected words.

Experiment 4

Participants. 28 participants, mostly undergraduates at Nijmegen University, were paid to take part in this experiment. All were native speakers of Dutch.

Materials. We selected 50 present participles with the inflectional suffix *-end*. Twenty-five of these present participles had a high Surface Frequency with an average of 5.83 (range 1.57–24.12, $\hat{s}$ 5.54), and 25 had a low Surface Frequency with an average of 0.21 (range 0.05–0.81, $\hat{s}$ 0.20). The two sets were matched for Base Frequency (high: mean 84.59, range 7.67–384.98, $\hat{s}$ 85.83; low: mean 85.12, range 7.55–400.55, $\hat{s}$ 90.38), Family Size (high: mean 33.9, range 2–251, $\hat{s}$ 54.2; low: mean 37.1, range 2–243, $\hat{s}$ 57.4), and for mean length in letters (high: 8.1, low: 7.7). We added 44 inflected past tense plural verbs with the suffix *-den*, which served as Experiment 3 above, and 90 inflected verbs in the third person singular. Each word was paired with a pseudo word with the same morphological structure which did not violate the phonotactic rules of Dutch. The experiment was preceeded by 30 practice trials. There was a short pause after the practice session, and another short pause during the experiment. In total, the experiment lasted about 20 minutes. The materials are listed in Appendix D.

Procedure. The procedure was identical to that of Experiment 2.

Results and Discussion

One participant made over 15% erroneous responses and was excluded from further analyses. Table 3 lists the mean reaction times and error scores for the two experimental conditions. The present participles with a high Surface Frequency elicited significantly shorter response latencies than the present participles with a low Surface Frequency ($t1(26) = -9.28, p = 0.00; t2(48) = -5.51, p = 0.00$). The differences in error scores were also reliable ($t1(26) = -6.86, p = 0.00; t2(48) = -3.55, p = 0.00$).

Even though the contrast between the high and low Surface Frequency conditions is substantially reduced compared to the contrasts

Table IV. Mean response latencies and error proportions for the present participles of Experiment 4 (means by participants).

		RT	$\hat{s}$ RT	Error	$\hat{s}$ Error
Present participles	High Surface Frequency	582	59.12	0.03	0.04
	Low Surface Frequency	660	70.68	0.13	0.08

in the previous experiments (5.83 versus 0.21 in Experiment 4, compared to 10.09 versus 0.30 in Experiment 3 and 18.34 versus 0.94 in Experiment 2), we still observe a large 78 ms effect of Surface Frequency that is supported by a post-hoc correlation of Surface Frequency with reaction time as well ($r = -0.58, t(48) = -5.00, p = 0.000$).

Interestingly, Surface Frequency and Base Frequency are not reliably correlated in the experimental materials of Experiment 4 ($r = 0.08, t(48) = 0.54, p = 0.590$), while at the same time Base Frequency and reaction time emerge as reliably correlated ($r = -0.28, t(48) = -2.03, p = 0.048$). Apparently, present participles with a high Base Frequency are responded to more quickly than present participles with a low Base Frequency. We interpret this to indicate that not only the full-form representations of the present participles are activated, but that during the parsing process the lexical representations of the base verbs themselves are activated as well. In other words, for the present participles, which tend to be lower-frequency forms, the parsing route also contributes effectively and independently of the full-form route to the process of lexical access.

The results of this experiment show, again, that complex words with a suffix that does not have rival suffixes may reveal clear Surface Frequency Effects. The balance of storage and computation for *-end* is not determined by its position on the regular-irregular scale, but by the balance in the frequencies of use of the base words and the participles themselves.

4. General Discussion

This study addresses the balance of storage and computation for fully regular Dutch inflected words. Whereas Marcus et al. (1995) and Clahsen et al. (1997) claim that the balance of storage and computation crucially depends on an affix having default status, i.e., it being prototypically regular to the exclusion of any other rival affix, our data show that the default status of affixes is irrelevant and that the linguistic desideratum of economy of description cannot be mapped directly onto cognitive models of lexical processing. Instead, the balance of storage and computation is determined by a wide range of linguistic *and* cognitive factors such as frequency of occurrence, computational complexity, and the relative costs of storage and computation in the mental lexicon.

Our argument against the projection of linguistic economy of description onto lexical processing is based on two sets of observations. The first set of observations concerns the formation of plural nouns in Dutch. A linguistic analysis of the regular and productive rival suppletive suffixes *-en* and *-s* shows that both can be considered to be prototypically regular and productive. They share most properties ascribed to default affixes by Marcus et al. (1995). A production experiment shows that participants can attach both suffixes to pseudo words, exactly as predicted from the regular complementary distribution of these suffixes. This experiment confirms that *-en* and *-s* are fully productive regular suffixes. Nevertheless, plural nouns in Dutch reveal substantial effects of Surface Frequency (Baayen, Dijkstra, and Schreuder, 1997), which indicates that many regular plurals have their own full-form access representations in the mental lexicon. Fully regular inflected words can be stored in the mental lexicon, even though they are prototypically regular.

The second set of observations concerns three verbal inflectional suffixes in Dutch, all of which have no suppletive rival affix and must therefore be considered to be prototypically regular. For the perfect participle *ge- -d*, the plural past tense suffix *-den*, and the present participle *-end*, we again observed substantial effects of Surface Frequency of some 80–100 ms. This shows that unambiguous default status does not imply the absence of storage in the mental lexicon. These results are in line with those obtained for the second and third person present tense suffix *-t* (*wandel-t*, 'you walk, he walks') studied by Schreuder, De Jong, Krott, & Baayen (1999), which likewise revealed a strong effect of Surface Frequency, and which is a prototypically contextual inflection.

Considered jointly with previous results for morphological processing in the visual modality (e.g., Sereno & Jongman, 1997; Taft, 1979; Burani, Salmaso, & Caramazza, 1984, Allegre & Gordon, 1999), we conclude that, at least for the visual modality, the notion of default is not a good predictor of the balance of storage and computation in Dutch. In a descriptive sense, an affix can be the default affix among a set of rival affixes, but this does not imply that the other rival affixes cannot be prototypically regular as well.

Effects of full-form storage for inflected words indicate that at some level of representation knowledge about the combined occurrence of the inflectional affix and its base word is stored. Our hypothesis is that the appropriate level of representation for the storage effects observed in the present experiments is that of the access representations, the level of representation at which form information is stored. Especially in the case of contextual inflection, we believe that it is unlikely that the semantics of the inflected form are stored as well at more central levels of representation. For instance, Baayen, Dijkstra, and Schreuder (1997) report the absence of Surface Frequency Effects for Dutch verb plurals in *-en* in visual lexical decision while matched noun plurals reveal a solid Surface Frequency Effect. However, in tasks which are especially sensitive to the process of visual and auditory identification of the form such as progressive demasking and auditory lexical decision, the very same verb plurals reveal the same Surface Frequency Effect as their matched nominal controls (Baayen, McQueen, Schreuder, & Dijkstra, 1999). We interpret this to indicate that these verb plurals have full-form access representations, but no separate central representations (in line with the Augmented Addressed Morphology model of Caramazza et al., 1988). In lexical decision, word meaning plays a more substantial role. With this task we can sometimes trace the difference between inherent inflection (noun pluralization) and contextual inflection (verb pluralization) at the central level, where noun plurals but not verb plurals have their own semantic representations.

Our findings have two main theoretical consequences. First, our data show that those who wish to argue against connectionist models or machine-learning based models (see Daelemans, Berck, & Gillis, 1995, for a computational model for morphology based on extensive storage in machine learning) cannot buttress their arguments with the claim that regular inflected words are never stored in the mental lexicon. Second, the present findings shift the focus of research from the question whether regular forms may or may not be stored to the question what factors might determine the balance of storage and computation.

This balance is not determined by linguistic regularity as such, but by a range of factors, such as frequency of use, the costs of storage, the costs of computation, and modality (Frauenfelder and Schreuder, 1992). First consider frequency of use. The three experiments with Dutch inflectional forms reported above show a pervasive effect of the frequency of the inflected form itself. However, when this Surface Frequency is relatively low, as for the Dutch present participles in Experiment 4, the frequency of use of the base word emerges as a second factor in visual lexical decision. The balance of storage and computation is clearly co-determined by the balance of Surface Frequency and Base Frequency.

Next, consider the costs of storage. The storage capacity of the human brain is enormous (Landauer, 1986), and probably more than large enough to allow storage of all commonly used complex words in languages with simple morphological systems such as English or Dutch. For languages such as Turkish or Finnish, in which one base can appear in thousands of other complex words, extensive storage may overtax human memory, and it may also be inefficient due to increasing retrieval times from memory. Not surprisingly, Niemi, Laine, & Tuominen (1994) report that full-form storage in Finnish is restricted to the domain of word formation. In their experiments, inflected words do not reveal any Surface Frequency Effects.

Costs are associated not only with storage, but also with computation. When morphological parsing is computationally intensive, lexical processing may be speeded up when a full-form representation is available. Such a full-form representation may provide a pointer to the correct syntactic and semantic representations in the central mental lexicon. In the parallel dual route model of Schreuder and Baayen (1995), Baayen, Dijkstra, and Schreuder (1997), and Baayen, Schreuder, and Sproat (1999), the direct route, using the full-form representation, may complete lexical access long before the parsing route, which uses the constituents, especially when the parsing route is slowed down due to ambiguities. One such ambiguity is caused by affixal homonymy. Bertram, Laine, Baayen, Schreuder, and Hyönä (1999) report that the Finnish partitive plurals with the suffix *-jA*, which also forms agent nouns, show clear effects of Surface Frequency. Apparently, on-line resolution of affixal homonymy is so expensive in real time that lexical access is completed more efficiently on the basis of the full form. A second kind of ambiguity arises when incompatible parses are present, as in Experiment 2, where we studied perfect participles in *ge-X-d*, which contain a regular derivational sub-parse in *ge-X*. For these participles, we observed an inhibitory effect of a high Base Frequency, which suggests that the parsing route has difficulties in resolving the morphotactic ambiguity. More in general, storage may enhance the parsing of longer complex words and the resolution of parsing ambiguities, as shown for our parallel dual route model by Baayen & Schreuder (1999a).

Modality (visual and auditory word recognition versus word production) plays an important role as well with respect to the balance of storage and computation. In speech production, inflected words have been argued to be assembled on-line (Roelofs, 1996; Janssen, 1999), driven by the semantics of the base word and the requirements of the syntactic context. In order to avoid overregularizations, precedence mechanisms are required that give priority to existing irregular forms over possible but unused regular forms. In language comprehension, by contrast, such a precedence mechanism is not required. When reading a regular present participle such as *wandel-end* ('walking'), the combination of constituents is already legitimate. Instead of having to assemble the correct form, the correct form is available in the input and has to be used as efficiently as possible to access the correct meaning, using both the full form and the constituents.

From this point of view, the claim advanced by Marcus et al. (1995) that the German noun plural suffix *-s* is the default and the one and only plural suffix for which rules are involved during lexical processing is rather counterintuitive for language comprehension. This claim entails that a mere 7% of German plural noun types and a mere 2% of German plural noun tokens would be processed by rule (see Table 5 in Clahsen, 1999). This would imply an exceptional degree of storage for German, even though a great many German noun plurals are completely regular from the perspective of language comprehension. For instance, given access representations for the *-en* and *-e* German plural suffixes as well as central representations that link these access representations to the syntactic and semantic representations of noun plurals, plural forms such as *Frauen* ('women') and *Hunde* ('dogs') can be readily parsed into their constituents. Not surprisingly, non-native speakers of German tend to have few difficulties with understanding German plurals while at the same time they may experience considerable difficulties to produce the correct plural forms. These considerations lead us to expect that upon careful examination the parsing route will be found to contribute more substantially to the lexical access of German noun plurals than Marcus et al. (1995) suggest.

Our examination of a range of fully regular and productive inflectional rules of Dutch shows that regularity and storage are not incompatible with each other. This insight cannot be gained by generalizing from a default affix with a quantitatively weak position in the language, such as the German plural in *-s*. For such an affix, high-frequency formations are atypical, and the likelihood that effects of full-form storage can be observed experimentally is small. For more productive inflectional affixes that give rise to more and higher frequency forms, storage in the mental lexicon is easier to observe. Although Marcus et al. (1995) and Clahsen et al. (1997) claim that the case of the German *-s* plural proves the rule that only default affixes are accessed on the basis of computation, the Dutch rules of noun and verb inflection suggest that this claim is based on an exception.

References

Allegre, M. and Gordon, P.: 1999, Frequency effects and the representational status of regular inflections, *Journal of Memory and Language* **40**, 41–61.

Baayen, R. H.: 1992, Quantitative aspects of morphological productivity, *in* G. E. Booij and J. van Marle (eds), *Yearbook of Morphology 1991*, Kluwer Academic Publishers, Dordrecht, pp. 109–149.

Baayen, R. H.: 1993, On frequency, transparency, and productivity, *in* G. E. Booij and J. van Marle (eds), *Yearbook of Morphology 1992*, Kluwer Academic Publishers, Dordrecht, pp. 181–208.

Baayen, R. H. and Renouf, A.: 1996, Chronicling The Times: Productive Lexical Innovations in an English Newspaper, *Language* **72**, 69–96.

Baayen, R.H. and Schreuder, R.: 1999a, Towards a psycholinguistic computational model for morphological parsing, *Philosophical Transactions of the Royal Society (Series A: Mathematical, Physical and Engineering Sciences*, to appear.

Baayen, R. H. and Schreuder, R.: 1999b, War and peace: morphemes and full forms in a non-interactive activation parallel dual route model, *Brain and Language* **68**, 27–32.

Baayen, R. H., Burani, C. and Schreuder, R.: 1997, Effects of semantic markedness in the processing of regular nominal singulars and plurals in Italian, *in* G. E. Booij and J. v. Marle (eds), *Yearbook of Morphology 1996*, Kluwer Academic Publishers, Dordrecht, pp. 13–34.

Baayen, R. H., Dijkstra, T. and Schreuder, R.: 1997, Singulars and plurals in Dutch: Evidence for a parallel dual route model, *Journal of Memory and Language* **36**, 94–117.

Baayen, R. H., McQueen, J., Dijkstra, A. and Schreuder, R.: 1999, *Dutch inflectional morphology in spoken- and written-word recognition.* Submitted.

Baayen, R. H., Piepenbrock, R. and Gulikers, L.: 1995, *The CELEX lexical database (CD-ROM)*, Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Baayen, R. H., Schreuder, R. and Sproat, R.: 1999, Modeling morphological segmentation in a parallel dual route framework for visual word recognition, *in* F. van Eynde and D. Gibbon (eds), *Lexicon Development for Speech and Language Processing*, Kluwer Academic Publishers.

Bertram, R., Baayen, R. H. and Schreuder, R.: 1999, Effects of family size for derived and inflected words, *Journal of Memory and Language*, to appear.

Bertram, R., Laine, M., Baayen, R. H., Schreuder, R. and Hyönä, J.: 1999, Affixal homonymy triggers full-form storage even with inflected words, even in a morphologically rich language, *Cognition*, to appear.

Bertram, R., Schreuder, R. and Baayen, R. H.: 1999, The balance of storage and computation in morphological processing: the role of word formation type, affixal homonymy, and productivity, *Journal of Experimental Psychology: Memory, Learning, and Cognition*, to appear.

Bloomfield, L.: 1933, *Language*, Allen and Unwin, London.

Bod, R.: 1998, *Beyond grammar: An experience-based theory of language*, CSLI publications, Stanford, CA.

Booij, G.: 1998, Phonological output constraints in morphology, pp. 143–163.

Booij, G. E.: 1977, *Dutch Morphology. A Study of Word Formation in Generative Grammar*, Foris, Dordrecht.

Booij, G. E.: 1993, Against split morphology, *in* G. E. Booij and J. v. Marle (eds), *Yearbook of Morphology 1993*, Kluwer Academic Publishers, Dordrecht, pp. 27–49.

Breiman, L., Friedman, J., Olshen, R. and Stone, C.: 1984, *Classification and Regression Trees*, Wadsworth International Group, Belmont, California.

Burani, C., Salmaso, D. and Caramazza, A.: 1984, Morphological structure and lexical access, *Visible Language* **18**, 342–352.

Caramazza, A., Laudanna, A. and Romani, C.: 1988, Lexical access and inflectional morphology, *Cognition* **28**, 297–332.

Clahsen, H.: 1999, Lexical entries and rules of language: a multi-disciplinary study of German inflection, *Behavioral and Brain Sciences*, to appear.

Clahsen, H., Eisenbeiss, S. and Sonnenstuhl-Henning, I.: 1997, Morphological structure and the processing of inflected words, *Theoretical Linguistics* **23**, 201–249.

Daelemans, W., Berck, P. and Gillis, S.: 1995, Linguistics as data mining: Dutch diminutives, *in* T. Andernach, M. Moll and A. Nijholt (eds), *CLIN V, Papers from the 5th CLIN meeting*, pp. 59–72.

Daelemans, W., Zavrel, J., van der Sloot, K. and van den Bosch, A.: 1999, TiMBL: Tilburg memory based learner reference guide 2.0, *Report 99-01*, Computational Linguistics Tilburg University.

De Jong, N. H., Schreuder, R. and Baayen, R. H.: 1999, The morphological family size effect and morphology. Submitted.

Dimmendaal, G. J.: 1987, Drift and selective mechanisms in morphological changes: the Eastern Nilotic case, *in* A. G. Ramat, O. Carruba and G. Bernini (eds), *Papers from the 7th international conference on historical linguistics*, John Benjamins, Amsterdam, pp. 193–210.

Gordon, P.: 1985, Level-ordering in lexical development, *Cognition* **21**, 73–93.

Grainger, J. and Jacobs, A. M.: 1996, Orthographic processing in visual word recognition: A multiple read-out model, *Psychological Review* **103**, 518–565.

Haeringen, C. B. v.: 1947, De meervoudsvorming in het nederlands, *Mededelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Letterkunde. Nieuwe Reeks.*

Jaeger, J., Lockwood, A. H., Kemmerer, D. L., Van Valin, R. D. and Murphy, B.: 1996, A positron emission tomographic study of regular and irregular verb morphology in English, *Language* **72**, 451–497.

Janssen, D.: 1999, *Producing past and plural inflections*, dissertation University of Nijmegen, 1999.

Kiparsky, P.: 1973, Elsewhere in phonology, *in* S. R. Anderson and P. Kiparsky (eds), *A Festschrift for Morris Halle*, Holt, Rinehart & Winston, New York, pp. 93–106.

Kiparsky, P.: 1982, From cyclic phonology to lexical phonology, *in* H. Van der Hulst and N. Smith (eds), *The structure of phonological representations*, Foris, Dordrecht, pp. 131–176.

Landauer, T. K.: 1986, How much do people remember? Some estimates of the quantity of learned information in long-term memory, *Cognitive Science* **10**, 477–493.

Laudanna, A. and Burani, C.: 1985, Address mechanisms to decomposed lexical entries, *Linguistics* **23**, 775–792.

Marcus, G., Brinkman, U., Clahsen, H., Wiese, R. and Pinker, S.: 1995, German inflection: The exception that proves the rule, *Cognitive Psychology* **29**, 189–256.

Marle, J. v.: 1985, *On the Paradigmatic Dimension of Morphological Creativity*, Foris, Dordrecht.

Marle, J. v.: 1986, The domain hypothesis: the study of rival morphological processes, *Linguistics* **24**, 601–627.

McClelland, J. L. and Rumelhart, D. E.: 1986, *On Learning the Past Tenses of English Verbs*, Vol. 2, The MIT Press, Cambridge, Mass., pp. 216–271.

Niemi, J., Laine, M. and Tuominen, J.: 1994, Cognitive morphology in Finnish: foundations of a new model, *Language and Cognitive Processes* **9**, 423–446.

Pinker, S.: 1991, Rules of language, *Science* **153**, 530–535.

Pinker, S. and Prince, A.: 1988, On language and connectionism, *Cognition* **28**, 73–193.

Pinker, S. and Prince, A.: 1991, Regular and irregular morphology and the psychological status of rules of grammar, *Proceedings of the 1991 meeting of the Berkeley Linguistics Society.*

Rickard, T. C., Healy, A. F. and Bourne Jr., E.: 1994, On the cognitive structure of basic arithmetic skills: Operation, order, and symbol transfer effects, *Journal of Experimental Psychology: Learning, Memory, and Cognition* **20**, 1139–1153.

Roelofs, A.: 1996, Serial order in planning the production of successive morphemes of a word, *Journal of Memory and Language* **35**, 854–876.

Rosenbaum, D. A., Vaughan, J., Barnes, H. J. and Jorgensen, M. J.: 1992, Time course of movement planning: Selection of handgrips for object manipulation, *Journal of Experimental Psychology: Learning, Memory, and Cognition* **18**, 1058–1073.

Schreuder, R. and Baayen, R. H.: 1995, Modeling morphological processing, *in* L. B. Feldman (ed.), *Morphological Aspects of Language Processing*, Lawrence Erlbaum, Hillsdale, New Jersey, pp. 131–154.

Schreuder, R. and Baayen, R. H.: 1997, How complex simplex words can be, *Journal of Memory and Language* **37**, 118–139.

Schreuder, R., Baayen, R. H., and Burani, C.: 1997, Parsing and semantic opacity in morphological processing. To appear in D. Sandra and E.Assink (Eds.), *Issues in morphological processing*, Kluwer, Dordrecht.

Schreuder, R., De Jong, N. H., Krott, A. and Baayen, R. H.: 1999, Rules and rote: beyond the linguistic either-or fallacy, *Behavioral and Brain Sciences*, to appear.

Schultink, H.: 1961, Produktiviteit als morfologisch fenomeen, *Forum der Letteren* **2**, 110–125.

Seidenberg, M.: 1987, Sublexical structures in visual word recognition: Access units or orthographic redundancy, *in* M. Coltheart (ed.), *Attention and Performance XII*, Lawrence Erlbaum Associates, Hove, pp. 245–263.

Seidenberg, M. and Hoeffner, J.: 1998, Evaluating behavioral and neuroimaging data on past tense processing, *Language* **74**, 104–122.

Sereno, J. and Jongman, A.: 1997, Processing of English inflectional morphology, *Memory and Cognition* **25**, 425–437.

Taft, M.: 1979, Recognition of affixed words and the word frequency effect, *Memory and Cognition* **7**, 263–272.

Tiersma, P. M.: 1982, Local and General Markedness, *Language* **58**, 832–849.

Venables, W. N. and Ripley, B. D.: 1994, *Modern Applied Statistics with S-Plus*, Springer, New York.

Appendix A

Experiment 1, number of responded plural suffixes (-s, -en, others)
Stressed one-syllabic pseudo words:
dreip (3, 46, 0); luif (1, 48, 0); stril (2, 47, 0); treig (3, 45, 1); horp (2, 47, 0); driem (1, 48, 0); grijk (1, 48, 0); krons (1, 48, 0); pruit (0, 49, 0); moek (4, 43, 2).
Two-syllabic pseudo words with an unstressed final syllable:
workel (49, 0, 0); drimmel (46, 1, 2); straggem (39, 4, 6); merkel (48, 1, 0); brezem (46, 1, 2); griekel (48, 1, 0); struimel (48, 0, 1); kloegel (48, 1, 0); zoppel (48, 1, 0); dreigel (49, 0, 0).
Two-syllabic pseudo words ending in schwa:
bame (20, 29, 0); kule (21, 28, 0); klijze (5, 44, 0); broele (16, 33, 0); stape (12, 37, 0); kloge (11, 37, 1); pliete (11, 37, 1); vule (19, 30, 0); loeke (16, 32, 1); hoele (16, 36, 0).
Two-syllabic pseudo words with an unstressed final syllable ending in the consonant -s:
bastus (0, 43, 6); muidus (0, 45, 4); briegus (0, 45, 4); klogus (0, 44, 5); stroebas (0, 49, 0); gienus (0, 44, 5); klettus (0, 43, 6); dietus (0, 42, 7); brenkis (0, 45, 4); glostis (0, 45, 4).
Pseudo words ending in a fully stressed vowel e or a:
kna (39, 10, 0); kra (39, 10, 0); pla (41, 7, 1); wa (39, 10, 0); za (40, 9, 0); dee (13, 36, 0); bee (22, 27, 0); kee (17, 32, 0); stree (9, 40, 0); vlee (12, 37, 0).
Pseudo words ending in the suffix -ing:
bestroeting (0, 49, 0); ontdruibing (1, 48, 0); herbanzing (1, 47, 1); begrijking (0, 49, 0); ontvloding (0, 49, 0); herbrekking (0, 49, 0); bepoesting (0, 49, 0); ontloeding(0, 49, 0); herstranking (2, 47, 0); beklusting(1, 48, 0).
Pseudo words ending in the suffix -(t)je:
megje (49, 0, 0); bralkje (49, 0, 0); bunkeltje (49, 0, 0); strimseltje (48, 1, 0); noogje (49, 0, 0); frienkje (49, 0, 0); braantje (49, 0, 0); gruimseltje (49, 0, 0); lannertje (49, 0, 0); kloertje (48, 1, 0).
Pseudo words ending in the suffix -isme:
kadisme (16, 36, 0); mylisme (10, 39, 0); microtalisme (12, 35, 2); tellinisme (13, 36, 0); heminisme (12, 36, 1); idiokatisme (12, 34, 3); exhilisme (13, 36, 0); profemisme (11, 38, 0); eudadisme (13, 35, 1); meteolyisme (11, 37, 1).

Appendix B

Experiment 2, Past participles with a high Family Size
geleverd (delivered) 585, gedoofd (extinguished) 630, gemiddeld (mediated) 636, gedoemd (doomed) 675, gedraaid (turned) 551, geleerd (learned) 531, gescheurd (ripped) 633, geboeid (chained) 580, geregeld (arranged) 672, geplaagd (teased) 535, gestuurd (sent) 529, gemengd (mingled) 618, gepleegd (committed) 596, gebouwd (built) 580, gegooid (thrown) 606, gesteund (supported) 618, geerfd (inherited) 731, gerekend (calculated) 661, gedroomd (dreamed) 622, geklemd (clasped) 600, gehinderd (impeded) 601, gekoppeld (coupled) 569, gefaald (failed) 586, gewisseld (swapped) 522, gespeeld (played) 566, gelegd (put) 600, gemarteld (tortured) 591, getrouwd (married) 559, geweigerd (refused) 532, gevuld (filled) 556.
Experiment 2, Past participles with a low Family Size
getraand (teared) 857, gegeurd (smelled) 861, gegrijnsd (smirked) 664, gesneld (hurried) 733, gekleurd (colored) 565, gekreund (moaned) 630, gecirkeld (circled) 674, gesuikerd (sugared) 684, gepeperd (peppered) 629, gezweefd (floated) 636, gevuurd (fired) 585, getafeld (dined) 729, geleegd (emptied) 626, gebeterd (improved) 700, genaamd (named) 705, gemodderd (messed around) 779, geboterd (buttered) 687, geboerd (burped) 773, gestoeld (based) 784, geruwd (roughened) 834, gewankeld (staggered) 661, gevlamd (flamed) 676, gedokterd (acted as a doctor) 750, gewinkeld (shopped) 753, geboomd (poled) 834, gestoomd (steamed) 671, gespeld (spelled) 746, geborreld (bubbled) 700, geraamd (estimated) 681, gewaterd (watered) 642.

Appendix C

Experiment 3, Past plural verbs with a high Family Size
gloeiden (glowed) 589, wisselden (swapped) 592, dwaalden (wandered) 541, vormden (formed) 566, breiden (knitted) 605, renden (ran) 539, spanden (stretched) 629, meenden (thought) 590, redden (saved) 551, dartelden (romped) 686, trilden (trembled) 630, vulden (filled) 641, speelden (played) 527, zeulden (dragged) 647, groeiden (growed) 538, wandelden (walked) 585, streelden (carressed) 540, hoorden (heard) 563, zweefden (floated) 530, noemden (named) 599, voerden (feeded) 608, dromden (swarmed) 761.
Experiment 3, Past plural verbs with a low Family Size
peinsden (pondered) 655, jammerden (moaned) 573, bezigden (employed) 734, pelden (pealed) 646, zegenden (blessed) 709, zuiverden (purified) 614, nummerden (numbered) 810, filterden (filtered) 956, oogden (eyed) 647, regelden (arranged) 633, zoogden (breastfed) 693,

wortelden (took root) 673, huisden (were housed) 697, nodigden (requested) 630, snelden (hurried) 690, schilden (peeled) 653, strandden (stranded) 674, stilden (stilled) 727, ruzieden (quarreled) 674, vaagden (faded) 723, scheelden (differed) 683, hongerden (starved) 611.

Appendix D

Experiment 4, Present participles with a high Family Size
weifelend (wavering) 663, draaiend (turning) 550, handelend (trading) 638, kreunend (moaning) 559, steunend (supporting) 548, wankelend (staggering) 587, juichend (jubilating) 572, aarzelend (hesitating) 627, brandend (burning) 536, zwijgend (being silent) 556, huiverend (shivering) 577, huilend (crying) 564, dreigend (threatening) 564, dwingend (forcing) 578, dansend (dansing) 582, wachtend (waiting) 537, piepend (sqeeking) 623, donderend (thundering) 701, fluitend (whistling) 530, zuchtend (sighing) 537, drinkend (drinking) 582, vloekend (cursing) 574, leunend (leaning) 636, druipend (dripping) 619, blinkend (blinking) 599.
Experiment 4, Present participles with a low Family Size
bouwend (building) 739, sleurend (dragging) 628, hechtend (attaching) 615, hijsend (hoiling) 619, haastend (hurrying) 619, louterend (ppurifying) 783, voegend (joining) 689, neigend (inclining) 592, luidend (sounding) 656, pleitend (pleading) 663, sterkend (strengthening) 687, gooiend (throwing) 670, vangend (catching) 659, barstend (bursting) 646, wensend (wishing) 617, wringend (wringing) 714, leidend (leading) 608, koersend (setting course) 751, regenend (raining) 670, schetsend (sketching) 646, rimpelend (wrinkling) 676, wemelend (teeming) 860, kleurend (coloring) 647, startend (starting) 574, wijdend (consecrating) 685.