Some implications of English spelling for morphological processing

Mark Aronoff, Kristian Berg and Vera Heyer
Stony Brook University / University of Oldenburg / Potsdam Research Institute for Multilingualism

In alphabetic writing systems, the most consistent correspondences hold between written and spoken segments. Although English spelling uses the Roman alphabet and is thus largely phonographic, it also encodes non-phonological distinctions such as those among homophonic words (e.g., *pair*, *pare*, *pear*). We review evidence that English spelling is to some extent morphographic at the level of suffixes: some suffixes (e.g. *-s* and *-ed*) have a single constant spelling (‹-s› and ‹ed›), despite the fact that they vary in phonological realization (*-s* is realized as [z], [s], or [əz], depending on the preceding segment); while other suffixes (e.g. *-ic*) are spelled differently from homophonous word-final phonological sequences (e.g. ‹relic› vs. ‹relick›). We explore the implications of our research for psycholinguistic findings on morphological processing of written English, with a special focus on 'affix stripping' processes. Psycholinguistic research has largely assumed the straightforward linguistic validity of morphographic spelling, without appreciating either its typologically unusual nature or the subtle and complex relation that it bears to morphology, phonology, and semantics.

Keywords: morphographic spelling, affix stripping, writing systems, inflection, derivation

1. Writing systems and affix stripping

Writing always encodes speech but sometimes encodes more. Sproat (2010) devotes an entire chapter to showing that "[e]vidently humans are restricted in what they can easily perceive in spoken language in such a way that sounds or some combinations of sounds form a natural basis for a representational system" (p. 73). Even the Chinese writing system, which was long thought to be word-based, "turns out to be largely constructed on the basis of sound" (DeFrancis,

ISSN 1871–1340 / E-ISSN 1871–1375
© John Benjamins Publishing Company
Uncorrected proofs - © John Benjamins Publishing Company

1984: 38). The key word here is *largely*. Although all writing systems represent sound (either individual segments or syllables or pieces of syllables), some represent other kinds of linguistic elements. The very first systems, like early Chinese, Sumerian, and Mayan, all had ways of representing individual words and are therefore called logographic.

Less common is for the writing system to encode morphemes, the basic building blocks of words. Modern Chinese writing may do so (Sampson, 1985). Most alphabetic systems do not. We have recently shown that English writing does and that over the last millennium the written representation of morphemes has become increasingly salient in this system (Berg & Aronoff, submitted). In what follows, we will explore the consequences of our findings for priming research on lexical recognition of visual words. It seems reasonable to conclude that this research, which purports to show that English readers engage in affix stripping of morphemes, shows also, or perhaps even instead, that these English readers are sensitive to the written representation of these morphemes. If we are right, then for many written languages other than English and French (another spelling system in which affixal morphemes are reliably encoded in addition to speech), such affix stripping should be much less likely to occur.

2. Morphographic spellings

Alphabets belong to the class of phonographic 'sound writing' systems, which represent or record a language by means of graphic symbols that correspond to stretches of sound. This term was first used in the early 19th century to distinguish sound-based systems from Chinese writing, where the symbols, which were termed *ideographic*, were (mistakenly, as it turns out) believed to represent concepts, as in the following sentence from Pierre DuPonceau, an early pioneer of American linguistics, cited in the OED:

> 1828 P. S. Du Ponceau Let. 7 July in Trans. Amer. Philos. Soc. (1838) 2 106: "Hence it [sc. the Chinese system of writing] is called ideographic, in contradistinction from the phonographic or alphabetical system of writing."

We use the term *morphographic* to distinguish yet a third type of writing, in which the system may represent morphemes. In some instances of morphographic writing, a particular morpheme may be written differently from a phonologically identical sound sequence. In others, phonologically distinct forms of the same morpheme may be written in the same way. In both, the spelling is sensitive to morphological information that is distinct from phonology. Compare, for example, the regular English past tense/past participle suffix spelled ‹ed› in the word

Uncorrected proofs - © John Benjamins Publishing Company

rapped (the past tense/past participle of *rap*) with the phonologically identical final letter ‹t› of the word *rapt*.[1] The ‹ed› spelling signals that we are dealing with the past tense/past participle suffix, and not just a sound that ends a word: it is morphographic. Conversely, this same ‹ed› spelling is famously sometimes pronounced [t], sometimes [d] (as in ‹rammed›, and sometimes [əd] (as in *ratted*). The pronunciation varies according to the last sound of the base verb, but the spelling is constant across the different pronunciations of the same morpheme: again, it is morphographic. We show here that this suffix is not an isolated case. The spelling of English suffixes is often consistent and distinct from homophonous final letter sequences. In the case at hand, we would say that ‹ed› is a morphographic spelling, while ‹t› is a final letter sequence that is homophonous with one phonemic reflex of ‹ed›. This observation holds for inflectional as well as derivational suffixes. We will address both in turn (2.1, 2.2), before turning briefly to non-morphological final letter sequences (2.3) and to typological considerations (2.4).

2.1 *Inflection*

Take the inflectional suffix ‹-s›, for example. It marks the regular plural of nouns (e.g. *cats*) and the 3rd person singular of verbs (e.g. *walks*). What is striking is that the consistency of this suffix is higher in written than in spoken language: While the phonological realization has three allomorphs [s], [z], and [ɪz] (as in e.g. *talks*, *runs*, *reaches*), the graphemic form is more consistent and only has two allomorphs ‹s› and ‹es› (in words ending in coronal fricatives, such as *catches, buzzes,* and *busses*). Of course, the distribution of the phonological allomorphs is phonologically determined; it hinges on the stem-final phoneme. Still, the spelling of the suffix is more consistent than its pronunciation, although both depend on phonology (cf. also Berg, Buchmann, Dybiec & Fuhrhop, 2014: 289ff.).[2]

So far, we have looked at ‹-s› from the perspective of the writer: In written English, the suffix is more consistently encoded than in spoken English. If we reverse this view and take the reader's perspective, there are more (and subtler) cues that the English writing system is sensitive to morphological information: Word-final single ‹s› is almost always 'reserved' for the suffix ‹-s› (for the following

1. We follow standard conventions and enclose letters in angled brackets (‹tripped›) and phonemes in forward slashes (/trɪpt/).

2. The contrast between the spelling of ‹-s› and that of the other frequent English inflectional suffix, ‹-ed›, is striking, but seldom noticed: one, ‹-ed›, includes in its spelling the vowel letter ‹e›, while the other, ‹-s›, has no vowel letter, even though, from a purely phonological point of view, this difference is meaningless. Elementary linguistics textbooks usually give their basic representations as /z/ and /d/, with no vowel for either one.

Uncorrected proofs - © John Benjamins Publishing Company

cf. Berg et al., 2014: 289ff.). There are only a few dozen monomorphemic words with final (single) ‹s› such as e.g. *lens*, *series* (see Table 1 below). This is in stark contrast to the much higher number of words that end with /s/ phonologically, e.g. *since*, *dense*. In other words: There are several hundreds of monomorphemic words that could be spelled with final ‹s›, but only a minor fraction of them is actually spelled with final ‹s›. Interestingly, this regularity holds only for words that consist of a *potential stem* followed by ‹s›. These are the cases that are in danger of a wrong analysis. If we spelled *‹dens› instead of ‹dense›, it could be decomposed into ‹den› and ‹s›. The ‹e› after the ‹s› prevents this reading. This is its only function; it does not mark any special phonographic correspondence (unlike, say, the final ‹e› of *pipe*, which marks the preceding ‹i› as 'long', in contrast with the 'short' ‹i› of *pip*). Words like *bonus* are not in danger of a wrong decomposition because ‹bonu› is not a 'good' English stem. The vast majority of stems in English either end with a consonant, ‹e›, or ‹y› (>93% of the lemmas in CELEX); before the suffix -*s*, however, ‹y› does not occur; it alternates with ‹ie› (e.g. *lady* – *ladies*, cf. Berg, 2013).

Note that this is a hypothesis that can be checked empirically: There should be comparatively few monomorphemic English words that contain a potential stem + final ‹s› (i.e. that end with consonant + ‹s› or with ‹e› + ‹s›), as opposed to words that contain an impossible/unlikely stem + ‹s›. This is indeed the case, as Table 1 shows. The numbers are based on CELEX (Baayen, Piepenbrock & Gulikers, 1995). More specifically, only those words that were annotated as monomorphemic, as morphologically obscure or as potentially containing a root were investigated. Entries with internal spaces and hyphens were excluded as well as recent borrowings ('language code': 'F, D, G, I, L, S'): This leads to a list of 12,772 words.

Table 1. Number of monomorphemic words with final ‹s› in three different constellations, based on CELEX (from Berg et al., 2014: 290)

Environment of single ‹s›	Nr. of words	%	Example
potential stem + ‹s› (consonant + ‹s› or ‹e› + ‹s›)	59	12%	‹lens›, ‹hives›
no potential stem + ‹s› (‹a, i, o, u› + ‹s›)	438	88%	‹tennis›
total	497		

N.B.: The table in Berg et al. (2014) also lists ‹y› with the vowels ‹a, i, o, u›. There are no words with ‹y› + ‹s› in the CELEX subcorpus we used, however.

Only a minority of monomorphemic words with final ‹s› (12%) contains potential stems. Final ‹s› is avoided in constellations where it might be misinterpreted as being morphemic. Take a moment to note, however, that the evidence presented

Uncorrected proofs - © John Benjamins Publishing Company

above is primarily graphemic, not psycholinguistic. The possibility to strip final ‹s› is inherent to the English writing system.

Fifty-nine words in Table 1 above are exceptions: They contain a potential stem followed by final ‹s›, and this ‹s› is not morphemic. A closer look reveals that most of them are pluralia tantum (cf. e.g., Bauer, Lieber & Plag, 2013: 123ff.) or names of diseases or scientific disciplines, which contain an *-s* suffix that is no longer productive, e.g., *scissors*, *breeches*, *shingles*, *measles*, *rabies*, *mathematics*, *craps*. Some of these words trigger plural subject-verb agreement, some do not. In either case, these pluralia tantum are not monomorphemic in the same sense in which *lens* is monomorphemic; final ‹s› marks at least a residue of plurality.

As hinted at above, another way to gauge the status of the 59 exceptions is to determine how many monomorphemic words could potentially be spelled with final ‹s›. If we restrict ourselves to monomorphemic words that end phonologically with consonant + [s], we can observe the following: Of the 218 words that fulfil these criteria, 197 are spelled without final ‹s› (e.g. *since*, *dense*, *box*). More than 90% of these words thus avoid final ‹s›. This in turn strengthens the correspondence between final ‹s› and the morphosyntactic functions the suffix has.

2.2 *Derivation*

The situation sketched above – a suffix is spelled consistently, and its spelling is consistently mapped onto the suffix – is not unique to inflectional suffixes. We will demonstrate this with the suffix *-ous*, though other suffixes behave similarly (for the following, cf. Berg & Aronoff, subm.). It is used to form adjectives from nouns (cf. e.g. Marchand, 1969: 339f.). This suffix is spelled consistently ‹ous› when it is word-final; there are no allomorphs in this position. There are 346 words with final ‹ous› in CELEX, and all of them are adjectives. It is instructive to determine how many words could potentially be spelled with final ‹ous›. Phonologically, the suffix is pronounced [ɨs].[3] If we take this as a criterion, there are 613 words with this phonological ending in CELEX.[4] As mentioned above, 346 of them are spelled with final ‹ous›.

3. This holds at least for connected speech. For a justification of the use of 'barred i' (i.e. the near-front near-close unrounded vowel) in unstressed ultimate syllables, see Flemming & Johnson (2007).

4. Words with the suffixes ‹-less›, ‹-ness›, ‹-itis›, and ‹-osis› were excluded from the search. We also excluded ‹ess› from this count. Although it is sometimes pronounced [ɨs], the pronunciation of individual words (as listed in OED) is highly variable.

Uncorrected proofs - © John Benjamins Publishing Company

Table 2. Words in the CELEX database that end in [ɨs] (but not in ‹less›, ‹ness›, ‹itis›, ‹osis›), grouped according to their graphemic final letter sequence

Final letter sequence	Nr. of words	Ratio	Example
‹ous›	346	56%	hazardous, nervous
‹us›	117	19%	bonus, genius
‹is›	72	12%	glottis, tennis
‹ice›	38	6%	office, service
rest	40	7%	
total	613	100%	

As Table 2 shows, the major graphemic alternatives are ‹us›, ‹is›, and ‹ice›. Only half the phonographically possible words are actually spelled with ‹ous›. What is more, there is a very clear and almost complementary distribution of graphemic final letter sequence and word class, as Table 3 shows.

Table 3. Cross-classification of final letter sequence (±‹ous›) and lexical category (±A) for all words in CELEX that end in [ɨs] (but not in ‹less›, ‹ness›, ‹itis›, ‹osis›)

	+‹ous›	−‹ous›
+A	346	6
−A	0	314

Words that end with ‹ous› are always adjectives, and adjectives that end with [ɨs] are almost always spelled with ‹ous›.[5] Something similar holds for final ‹ess›, which is a suffix itself. It denotes female persons or animals (cf. Marchand, 1969: 286ff.). Of the 53 words that end in ‹ess›, 47 actually refer to females (89%). Final ‹ess› is thus a reliable cue for femaleness. In sum, one can think of ‹ous› and ‹ess› as tags that are attached to words and that identify them as belonging to some syntactic (‹ous›) or semantic (‹ess›) class.[6] Note that ‹ous› is just one derivational suffix for

5. The six non-‹ous› adjectives are *apprentice*, *novice*, *primus*, *bogus*, *emeritus*, and *traverse* (in BrE pronunciation). The status of *apprentice* and *novice* as adjectives is unclear, and *primus* has a very limited distribution as an adjective (e.g. in "Jones primus"). This makes the data in Table 3 even clearer.

6. Recent research has shown that phonologically homophonous words and morphemes may not be realized phonetically identically. For example, Plag, Homann and Kunter (2015) find that different -*s* morphemes differ systematically in duration, and that non-morphemic -*s* differs from morphemic -*s* (non-morphemic longest, suffixed -s is shorter, and cliticized -*s* is the shortest. Interestingly, the three groups of -*s* also differ in their orthographic properties. We have not investigated whether the various instances of [ɨs] that we have identified are phonetically distinct.

Uncorrected proofs - © John Benjamins Publishing Company

which this relation can be shown. In Berg and Aronoff (subm.), something similar is demonstrated for ‹ic›, ‹al›, and ‹y›.

Note that this is not the case for the corresponding phonological forms. They lack this kind of tagging: *nervous* and *service* rhyme, and there is nothing in the phonological make-up of *nervous* that tells the listeners that it is an adjective.

2.3 *Graphotactic spellings*

Apart from a strong correlation between suffixes and their graphemic form, English also exhibits purely graphotactic spelling patterns for final letter sequences. These sequences are recurring letter strings with distributional properties. In English, individual final letter sequences reliably co-occur with consonant doubling or non-doubling (cf. Berg, 2016). For example, almost all words with final ‹-le› occur with consonant doubling (e.g. *rattle*, *shuttle*, *kettle*). Words with final ‹-it›, on the other hand, almost never occur with double consonants (e.g. *visit*, *spirit*, *edit*). What is more, sometimes final letter sequences with different distributions are homophonous. For example, final ‹-it› and final ‹-et› correspond to the same phonological syllable rhyme (at least in connected speech); but ‹-it› hardly occurs with double consonants, while ‹-et› almost always does (e.g. *cricket*, *bonnet*, *mullet*). For the writer, the decision for one graphemic form (that of the final letter sequence) determines another graphemic form (consonant doubling or non-doubling), or vice versa. As a result, final letter sequences may be psychologically 'real' entities that are important for writers (and readers) of English.

2.4 *Typological considerations*

Linguists strive to explain language universally and not for individual languages specifically. So, the question that arises from the above discussion is how specific these findings are to English. Theoretically, they can be extended to some, though not all, languages with a long tradition in spelling. Writing systems that reliably encode a given phoneme with one and only one grapheme ('shallow' writing systems in the sense of Katz & Frost, 1992) should be less likely to exhibit the kind of morphographic spellings we find in English. Writing systems with complex phoneme-grapheme correspondences (Katz & Frost's 'deep' writing systems), on the other hand, are potential candidates for systems with this feature.[7] Starting

7. But note that complex phonographic correspondences do not necessarily entail morphographic spellings; a deviation from one-to-one correspondences can have many reasons, e.g. a high number of idiosyncratic spellings.

Uncorrected proofs - © John Benjamins Publishing Company

from this assumption, we will very briefly review the spelling system in three European languages with varying degrees of phonographic consistency, namely French, German, and Spanish. French is a 'deep' writing system, Spanish is 'shallow'; German is somewhere in between (cf. Meisenburg, 1998). Note that the following remarks are necessarily brief and sometimes anecdotal as this is largely uncharted territory.

– In French, the better part of inflectional morphology exists only in spelling and is not mirrored in spoken language (cf. e.g. Catach, 1980). For example, the forms *monter*, *montez*, *monté*, *montée*, *montés* are all homophonous. But what is more is that many suffixes have unique spellings that set them apart from homophonous final letter sequences. The spelling of the verbal inflectional suffix ‹ons›, for example, is exclusive for this suffix (e.g. *voulons* 'want. 3-Pl'). Homophonous final letter sequences are spelled differently (as ‹on›, e.g. *balcon*). This holds for a number of suffixes. Most remarkable are the silent inflectional suffixes ‹-e›, ‹-es›, and ‹-ent›. Four of the six persons in the indicative present are phonologically identical but there are three different spellings.
– In German, inflectional suffixes are not consistently distinguished from homophonous final letter sequences (cf. Berg, in press). For example, there are more than 100 morphologically simple nouns that end with ‹en› (e.g. *Schatten* 'shadow'). These look like words in which ‹en› is a number/case suffix (e.g. *Betten* 'bed.Pl') or the infinitival suffix (e.g. *reden* 'talk.Inf'). For derivational suffixes, there seems to be much less homography. The only suffix with substantial overlap with a final letter sequence is the agentive suffix ‹-er› (as in *Bäcker* 'baker'). Here, we also find more than 100 monomorphemic words with final ‹er›, e.g. *Zimmer* 'room', *Leber* 'liver', *Finger* 'finger'.[8]
– In Spanish, inflectional suffixes are also not consistently distinguished from homophonous final letter sequences. For example, the preterite 1st person forms of verbs ending with ‹-ir› has the graphemic form ‹í› (e.g. *viví* 'live.1Ps-Prt'). This spelling is not exclusively used by the suffix, however. There are many words with homophonous endings that are also spelled with final ‹í› (e.g. *baladí* 'trivial').

From the above review of different languages, we can conclude that the spelling of a suffix does not indicate the presence of that suffix equally clearly in all

8. Although German is not morphographic with respect to affixes, one reviewer has pointed out to us that German reliably encodes stems ('Stammkonstanzschreibung'), so that homophonous forms such as ‹hasten› 'to rush' and ‹hassten› 'hated' are orthographically distinguished, with the former being morphologically related to the stem ‹Hast›, the latter to the stem ‹hass-›.

Uncorrected proofs - © John Benjamins Publishing Company

languages. While English and French show very high degrees of affix 'salience' (i.e. a specific spelling consistently refers to an affix), the spelling of affixes in German and Spanish is less unique.

3. Morphographic spelling and language processing

In psycholinguistic research, specific strings of letters or sounds that represent affixes have been in the spotlight for decades. The focus of this research has been whether or not these sequences of letters or sounds are perceived as an affix during language processing or whether morphologically complex words are processed as one unit. In other words, this research has investigated whether morphologically complex forms such as *walker* are decomposed into the base *walk* and the agentive suffix *-er* or whether they are accessed as full forms in the mental lexicon in the same way as morphologically simplex words like *cake*.

An experimental technique used to address the question of decomposition is the priming paradigm. In such a paradigm, participants' reaction times to the base word are measured (e.g. in a word/nonword discrimination task); the response times to the target are then compared for a condition where the corresponding complex form preceded the target and a condition where the preceding prime word was unrelated. If reaction times to *walk* are faster when the prime word was *walker* in comparison to *singer*, for example, this is interpreted as evidence that the base *walk* was already accessed during prime processing, which reduces the reaction times to the target *walk* as the lexical entry has been pre-activated. There are different variants of the priming paradigm, with different modalities of presentation (visual or auditory) and different prime durations, tapping into different processing stages. For instance, in cross-modal priming, primes are presented auditorily and targets visually (or vice versa); in masked priming, the prime is presented visually for a very short time (usually 60 milliseconds or less) and preceded by a mask (e.g. a row of hash marks) so that participants are not consciously aware of the primes. For methodological reviews, see e.g. Marslen-Wilson (2007) or Forster, Mohan and Hector (2003).

If we assume that the consistent (morphographic) spelling of grammatical units is reflected in language processing, we would expect facilitation effects for morphologically related prime-target pairs in the visual modality, i.e. affixes such as ‹-ous› or ‹-er› are likely to be stripped off and the base accessed subsequently. Furthermore, due to its salience as an affix, ‹-er› might not only be removed from derived forms such as *walker* but also from pseudo-derived ones like *corner*, thus leading to access of *walk* and *corn*. Indeed, masked priming studies have found facilitation effects not only following derived but also following pseudo-derived

Uncorrected proofs - © John Benjamins Publishing Company

forms (e.g. Rastle, Davis & New, 2004; Andrews & Lo, 2013; for meta analyses, see Rastle & Davis, 2008; Feldman, O'Connor & Moscoso del Prado Martín, 2009; Davis & Rastle, 2010). Crucially, these facilitation effects were specific to primes with endings that were genuine affixes or homographs of these, whereas primes with non-morphological endings did not accelerate target recognition (e.g. *brother* primed *broth* but *brothel* did not, e.g. Rastle et al., 2004).

However, once there is more time to process the prime word, the so-called *corner–corn* effect vanishes. For instance, Rastle, Davis, Marslen-Wilson and Tyler (2000) did not find significant priming effects for pseudo-derived items (but for genuine derived ones) when primes were presented longer in a masked paradigm (72 ms) or overtly for 230 milliseconds, while the same items had shown significant facilitation in a masked priming paradigm with a short prime duration (43 ms). This suggests that only early processing stages are influenced by the morphographic information and that the salience of the letter string that constitutes an affix is overridden by additional information available from the input that is being processed. More specifically, morpho-semantic information (i.e. that *corner* and *corn* are not morphologically related) has been claimed to affect whether or not priming occurs. Researchers do not agree, though, at which point during processing this type of information is utilized. While some argue for a delayed integration of semantic information, others claim an immediate influence of semantics on the processing of (pseudo-)derived forms (for extensive discussions, see Rastle & Davis, 2008; Feldman et al., 2009). Despite more recent evidence using brain potentials allowing for a more detailed temporal resolution (e.g. Lavric, Elchlepp & Rastle, 2012) or applying more advanced statistical analyses (e.g. Feldman, Milin, Cho, Moscoso del Prado Martín & O'Connor, 2015), this issue has not been resolved yet.

While previous research has approached the processing of morphologically complex words from a structural perspective (i.e. exploring the morphological structure), the contributions of formal spelling aspects have largely been neglected. In the following sections, we will look at previous priming research through 'spelling glasses', discussing the consequences of morphographic spelling for psycholinguistic research and, more specifically, morphological processing. While the sections raise questions and suggest future directives for psycholinguists to incorporate the special characteristics of the English spelling system into their research, we also attempted, where possible, to shed light on the influence of the spelling consistency on reported priming effects by looking at the results from a different angle than the one adopted in the original papers. In Section 3.1, we address the issue of modality, asking whether the above effects are restricted to visual stimuli (i.e. the domain of spelling) or whether they extend to auditory stimuli. Sections 3.2 and 3.3 explore the salience of final letter strings, investigating whether graphotactic spellings (i.e.

Uncorrected proofs - © John Benjamins Publishing Company

frequent non-morphological final letter sequences such as ‹-it›, cf. Section 2.3) induce similar priming effects and whether morphographic affixes form units that can be primed themselves. Widening the scope from the discussion of pseudo-derivation, we will treat pseudo-inflection in Section 3.4, following up on the high salience of the English inflectional suffixes ‹-ed› and ‹s› we saw in Section 2.1. Finally, we will further expand our discussion to other languages, exploring the observations in Section 2.4 about different degrees of morphographic suffix spellings in English and French versus German and Spanish.

3.1 *Are affixes only detected when complex words are presented visually or also when they are presented auditorily?*

As shown in Section 2 above, affixes are considerably less salient in spoken language in comparison to visual presentations due to the existence of various final letter sequences that are homophonous to affixes. As a result, one could argue that affixes are more difficult to detect in auditory stimuli, resulting in a reduction or absence of the *corner–corn* effect in auditory priming. Indeed, facilitation effects for pseudo-derived or semantically opaque items were absent in previous studies with auditory primes (e.g. Marslen-Wilson, Tyler, Waksler & Older, 1994; Marslen-Wilson & Zhou, 1999). For instance, in a cross-modal priming study, in which primes were presented auditorily and targets visually, Marslen-Wilson et al. (1994) did not find significant facilitation effects for opaque pairs such as *casualty – casual* while the transparent *punishment* primed *punish* reliably.

However, while this lack of a priming effect for auditorily presented *corner*-type forms could be explained by the reduced salience of affixes in the auditory modality, the detection of affixes in transparent forms such as *walker* should be similarly difficult. As such transparent forms consistently cause priming in auditory designs, though, the explanation for the absence of the *corner–corn* effect for auditory stimuli rather lies in the difference between the processing stages tapped by masked versus auditory priming paradigms. Masked priming taps very early processing stages, in which an affix-driven segmentation takes place, involving access representations (where *walker* and *corner* are treated similarly); overt priming (including auditory paradigms), on the other hand, allows for longer prime processing thus involving the connections between the lexical entries of morphologically complex forms and their bases (consequently distinguishing *walker* and *corner* due to the lack of connections between the latter and the pseudo-stem *corn*; cf. e.g. Marslen-Wilson, Bozic &Randall, 2008).

A way to investigate whether the observed absence of significant facilitation effects following auditorily presented opaque primes is indeed due to the different level of processing tapped by paradigms with auditory stimuli would be to

Uncorrected proofs - © John Benjamins Publishing Company

mask the auditory primes. In 2005, using French stimuli, Kouider and Dupoux introduced a technique they referred to as 'subliminal speech priming', in which primes are "time compressed and 'hidden' within a stream of spectrally similar unintelligible speechlike noise" (p. 617) and the targets are superimposed onto this stream at the prime onset. While Kouider and Dupoux found consistent repetition priming throughout different compression rates (ranging from 35 to 70%), morphological prime-target pairs (i.e. gendered nouns such as *cousin* – *cousine* 'male cousin – female cousin') did not show facilitation effects at high compression rates – in contrast to what has been found in visual masked priming. So far, this technique has not received much appreciation in psycholinguistics, though – especially not for morphological processing, with subsequent studies concentrating on formal overlap instead (Taft, Castles, Davis, Lazendic & Nguyen-Hoan, 2008; Davis, Kim & Barbaro, 2010). To our knowledge, only one recent study used this technique to investigate morphological processing: Ussishkin, Dawson, Wedel and Schluter (2015) found root priming in Maltese, a Semitic language; however, due the nature of Ussishkin et al.'s stimuli the observed effects could also be phonological rather than morphological in nature (p. 1106). The investigation of English semantically transparent and opaque affixed items versus orthographic/phonological controls such as *brothel* – *broth* could help to disentangle different sources of information that might be accessed during early speech processing. If affixes were indeed more difficult to detect in the auditory modality, we would expect reduced or absent facilitation effects for *corner*-type items in comparison to transparent forms such as *walker* (and no priming effects for form controls such as *brothel*). Note however, that the comparability of masked visual and masked auditory priming has not been researched to a sufficient extent. It is not yet established that auditory masked priming indeed taps the same processes as its well-established visual counterpart. As a result, more research on the method itself might be required before we could draw strong conclusions about the *corner*–*corn* effect in the auditory modality.

3.2 *Are priming effects restricted to affixes or can frequent final letter sequences induce priming as well?*

If we assume that affixes become salient through consistent spelling as well as frequency of occurrence, it is possible that similar effects might be observed for other frequently-occurring letter sequences; more specifically, readers might be sensitive to final letter sequences such as ‹-le› and ‹-it› that are, as described in Section 2.3 above, subject to graphotactic spelling patterns. If this is true, we would expect priming effects for items with primes that do not have an affix (i.e.

Uncorrected proofs - © John Benjamins Publishing Company

that are not morphologically related to the target) but have a (non-morphological) final letter sequence that is very common in the language.

Although various priming studies have included control conditions with non-morphological final letter sequences in order to control for potential confounds due to shared initial letters in derived pairs such as *walker – walk* (e.g. Rastle et al., 2004; Marslen-Wilson et al., 2008), distributional properties of the final letter sequences were not controlled, with the final letter sequences in the orthographic item sets ranging from single letters (e.g. ‹t› in *sight – sigh*) to more or less frequent bigrams (e.g. ‹it› in *pulpit – pulp* vs. ‹xy› in *galaxy – gala*) to infrequent longer letter sequences (e.g. ‹hesis› in *parenthesis – parent*; examples taken from Rastle et al., 2004). As a result, the diversity of final letter sequences might have masked potential facilitatory effects stemming from a subset of orthographic items with frequent final letter sequences.

In order to investigate the possibility of priming effects due to frequent final letter sequences, we searched for masked priming studies with orthographic item sets of this kind, for which we could retrieve priming effects for individual items. These studies were Rastle et al. (2000) and Rastle and Davis (2003), both providing the mean response times per item (following related and unrelated primes) in their appendices, as well as the data from Heyer and Clahsen (2015), to which we had access. For these three studies, Figure 1 displays the magnitude of priming per item in relation to the token frequency of the respective final letter sequence (as obtained from the CELEX database, cf. Baayen et al., 1995). From the Rastle et al. (2000) study, we excluded the overt condition (SOA: 230 ms). Furthermore, we excluded items that contained pseudo-suffixes (e.g. *corner – corn*), resulting in 26 data points in the Heyer and Clahsen, 45 in the Davis and Rastle and 24 in the Rastle et al. data set (number of unique final letter sequences: 13, 20 and 12 respectively). As can be seen in Figure 1, priming effects tended to be smaller for items with high-frequent final letter sequences in the Heyer and Clahsen study but to increase with frequency in the other two studies. We conducted linear models testing how priming effects per item were modulated by the (centered) token frequency (‘Ending Frequency’). Furthermore, we included the length of the final letter sequences (as the length might also affect potential segmentation processes) as well as the ratio between prime and target (log) token frequency (as high-frequency orthographic neighbors have been shown to cause inhibition, cf. Segui & Grainger, 1990) as centered factors (‘Length’ and ‘Prime/Target Frequency’) in our linear models. While the models did not reveal any significant modulations by Ending Frequency (ts < 0.52) Length (ts < 0.90) or Prime/Target Frequency (ts < 1.59) in the first two studies, Ending Frequency (Est. = 18.22, $t = 218$, $p = .041$), but not Length (Est. = 28.77, $t = 1.62$, $p = .121$) or Prime/Target Frequency (Est. = –37.24, $t = -0.66$, $p = .518$), modulated priming effects in the Rastle et al. data.

Uncorrected proofs - © John Benjamins Publishing Company

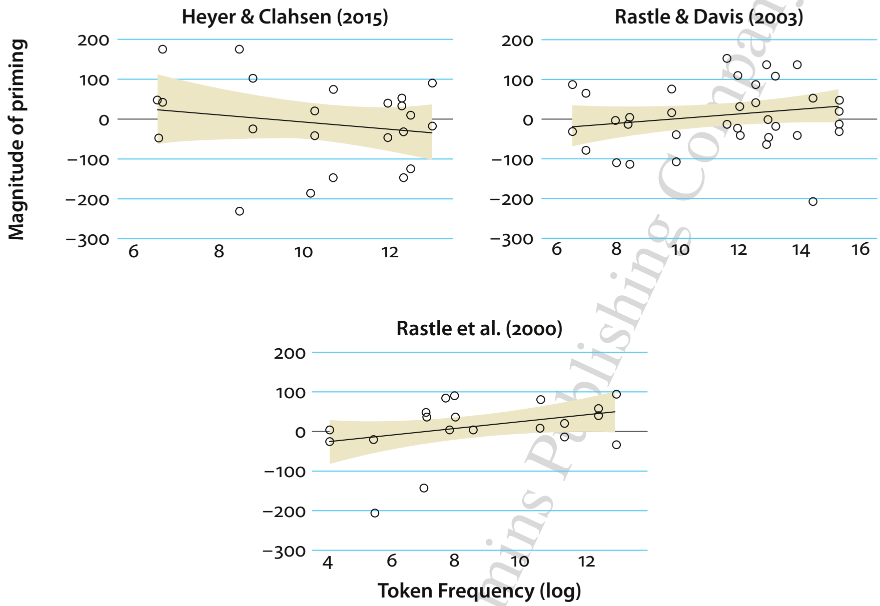

Figure 1. Modulation of the magnitude of priming per item by the token frequency of final letter sequences from the orthographic item sets in Heyer & Clahsen (2015), Rastle and Davis (2003) and Rastle et al. (2000)

Although the results from the above analysis were mixed, they still indicate that the nature of the final letter sequences might have an effect, suggesting that high-frequent (non-morphological) sequences are potentially stripped off. Note that the analyzed data was not designed with graphotactic aspects in mind and the analysis is necessarily adhoc. So, in order to investigate whether there is 'final letter sequence stripping' (instead of or in addition to 'affix stripping'), future research should contrast sets of orthographic items with graphotactic letter sequences (e.g. *socket* – *sock*) and infrequent final letter sequences (e.g. *galaxy* – *gala*), ideally in comparison to morphological items.

3.3 *Are affixes units that can be primed as well?*

If affixes are units with psychological reality, they might also prime each other. Most previous research has looked at stem priming but, if affixes are units by themselves, they might also be represented in the mental lexicon. There are two different ways in which an affix (either in isolation or as part of a complex word) could prime (another) complex form with the same affix: First, affixes might have their own lexical entries (as assumed in decomposition models such as Taft &

Uncorrected proofs - © John Benjamins Publishing Company

Nguyen-Hoan's (2010) model, for example), resulting in similar effects as for free stems (i.e. *walker* does not only prime *walk* but also *-er*). Second, words with the same affix might form 'families', i.e. lexical entries that share an affix are connected in the mental lexicon similarly to what has been proposed for related stems (see e.g. Bertram, Baayen & Schreuder, 2000).

So far, only a few studies have investigated affix priming effects and even fewer have used English as target language. In a cross-modal priming paradigm, Marslen-Wilson, Ford, Older & Zhou (1996) reported significant priming for suffixed words preceded by another complex form (e.g. *darkness* priming *toughness*) – especially when the affixes were productive ones. For pseudo-derived targets (e.g. *darkness* – *harness*), however, they did not find facilitated target recognition, suggesting that the pseudo-affix was not primed. This would be in line with the 'family' explanation, in that *darkness* and *toughness* form a family in the mental lexicon whereas *harness* is not part of this family as it is not genuinely affixed.

Note, though, that presenting the pseudo-derived form as target for lexical decision entails conscious processing of the word whereas priming effects for *corner*-type items have usually only been reported when the pseudo-derived forms were processed unconsciously (i.e. as primes under masked conditions). As a result, pseudo-affixes might prime genuinely affixed targets under masked conditions. However, to our knowledge, this has not yet been investigated in English or any other language.

Another design that can be used to put the 'family' explanation to the test, is the use of complex nonwords. In a recent masked priming study, Crepaldi, Hemsworth, Davis and Rastle (2015) used nonwords that were created out of existing stems and affixes (e.g. *sheet-er*) as primes for existing complex forms (e.g. *teacher*). They found significant facilitation for complex targets preceded by nonwords with the same affix in comparison to nonwords with another affix (e.g. *sheet-al*). Crucially, no such effects were observed for nonword primes with orthographic final letter sequences such as *colour-el*, indicating that the above priming effects originated from the shared morphological units rather than the pure letter overlap.

3.4 *Are there also priming effects for pseudo-inflection?*

While pseudo-derivation has been widely studied in the past decades, pseudo-inflection has received much less attention. One of the reasons for the neglect of pseudo-inflection might be that the spectrum of inflection in English is rather limited and, as shown in Section 2.1 above, the spelling of the English past tense

Uncorrected proofs - © John Benjamins Publishing Company

and plural is very morphographic, resulting in very few simplex forms that could be 'mistaken' for complex ones. In the auditory modality, the classification of past tense forms is less clear, though, with many forms ending in /t, d/. Crucially, the mere occurrence of a word-final /t/ or /d/ does not allow for an identification of a past tense form; instead, the voicing of the affix depends on the voicing of the preceding consonant. For instance, *kissed* is pronounced with the unvoiced /t/ as ‹s› is unvoiced and *hugged* with /d/ as the ‹g› is voiced.

Psycholinguistic studies have used this characteristic of the English past tense to investigate whether or not the so-called inflectional rhyme pattern is observed in decompositional processes. If word-final /t, d/ is stripped off automatically assuming this to be a past tense form, it should not matter whether the preceding consonant is voiced or voiceless. If, however, the inflectional rhyme pattern has an impact, primes that comply with this pattern (e.g. *mild*) – but not those that do not (e.g. *belt*) – should cause facilitated recognition of the corresponding 'stems' as targets (i.e. *mile* and *bell* respectively). This is indeed what auditory priming studies have found (e.g. Tyler, Randall & Marslen-Wilson, 2002; Post, Marslen-Wilson, Randall & Tyler, 2008).

In the visual modality, on the other hand, the above examples should not be 'mistaken' for past tense forms as the spelling does not comply with the very consistent suffix ‹-ed›. For instance, Kielar, Joanisse and Hare (2008) used pseudo-regular pairs such as *chest* – *chess* in a masked priming paradigm and did not find any facilitation for such pairs. In fact, *chest* inhibited the recognition of *chess* at a prime duration of 67 milliseconds, indicating that the two forms appear to compete instead. Inhibition between orthographic neighbors is not unusual and has been reported elsewhere before – usually at longer prime durations or overt presentations, though (e.g. Rastle et al., 2000, Pastizzo & Feldman, 2002; Longtin, Segui & Hallé, 2003).

With respect to forms that contain the letter sequence ‹ed› and an existing stem, to our knowledge, no previous study has systematically looked at pseudo-inflected forms. This is likely due to the fact that the ‹ed› spelling seems to be very much restricted to the affix and only a handful of forms deviating from the morphographic spelling exist. For instance, the opaque item set in Rastle et al. (2004) contained three prime-target pairs that are exceptions (*united* – *unit, stilted* – *stilt, crooked* – *crook*). As a result, it might not be feasible to extend the *corner–corn* research to inflection in English; however, other languages might be more suitable for that.

Uncorrected proofs - © John Benjamins Publishing Company

3.5 *How is affix salience reflected in psycholinguistic research from different languages?*

As discussed in Section 2.4 above, languages differ with respect to their spelling in that English and French are fairly morphographic, while German and Spanish exhibit more ambiguities with respect to their spelling of affixes and non-affixes. As a result, affix stripping might be more pronounced in the salient contexts of the former two languages, and less so for the latter. Interestingly, the *corner–corn* effect has been shown for English (e.g. Rastle et al., 2004; Andrews & Lo, 2013, amongst others) and French (e.g. Longtin et al., 2003; Diependaele, Sandra & Grainger, 2005) but not for German or Spanish. With respect to French, for example, Longtin et al. (2003) reported patterns of results that were analogous to the English ones presented above, with significant facilitation effects for French pseudo-derived pairs such as *baguette* ('little stick'/'French bread') – *bague* ('ring') in the visual modality (under masked conditions) but not when primes were presented auditorily.

Although pseudo-derived items have been investigated in a selection of languages other than English and French – namely Dutch, Italian, Serbian and Russian (cf. e.g. Rastle & Davis, 2008: Table 1), to our knowledge, no published masked priming study has investigated pseudo-derived forms in German or Spanish in an analogous way to the above studies. However, there are a few studies that address German and Spanish pseudo-complex forms to some degree.

With respect to German, there are a doctoral thesis with suffixed forms (Otto, 2012) and several studies by Smolka and colleagues looking at prefixed verbs (Smolka, Komlósi & Rösler, 2009; Smolka, Preller & Eulitz, 2014). Otto (2012) replicated Rastle et al.'s (2004) finding of priming for English pseudo-derived items such as *corner* – *corn* but, in her equivalent experiment with German stimuli, facilitation effects surfaced for semantically transparent items (e.g. *fruchtig* 'fruity' – *Frucht* 'fruit') but not for semantically opaque ones (e.g. *Zeitung* 'newspaper' – *Zeit* 'time'), suggesting that pseudo-suffixes are not stripped off automatically and priming requires an authentic morphological relationship in German.[9] Smolka and colleagues, on the other hand, found priming effects for opaque

9. Note that Otto's materials were confounded, in that several of the targets were strictly speaking not the corresponding base (e.g. *Zauber* 'magic' instead of *zaubern* 'to perform magic' for *Zauberer* 'magician'). However, while this characteristic of the design might be excused as those noun targets often coincided with the verbal stem (here: *zauber-*), the same logic was not applied for the pseudo-derived forms, where various items could be interpreted as transparent (e.g. *Betonung* 'emphasis' priming *Beton* 'cement' which coincides with the verbal stem of *betonen* 'to emphasise').

Uncorrected proofs - © John Benjamins Publishing Company

prefixed verbs (e.g. *umkommen* 'to perish' – *kommen* 'to come') in overt priming paradigms, thus claiming that, in contrast to English where effects for opaque items are absent in overt priming studies, decomposition is obligatory in German. However, it is questionable whether this interpretation is justified because many of Smolka et al.'s items are not genuinely (pseudo-)prefixed but so-called separable verbs (i.e. the 'prefix' is presented in isolation in several inflected forms, e.g. *aufhören* 'to stop' – *Ich höre auf.* 'I stop.'), which could have increased the separation between 'prefix' and 'stem'.

Concerning Spanish, Lázaro, Illera and Sainz (2015) claim to have found evidence for morpho-orthographic decomposition. In a masked priming experiment, they found significant facilitation for both derived and pseudo-derived targets when the corresponding suffix was used as prime (e.g. *ero* primed both *jornalero* 'journalist' and *cordero* 'lamb'), while no such facilitation was found for orthographic primes (e.g. *bro* did not prime *cerebro* 'brain'). However, the presentation of the (pseudo-)suffixes in isolation might have led to an artificial increase in facilitation. Furthermore, as the final letter sequences in the orthographic set were not matched to the suffixes with respect to frequency (also see Section 3.2 above), it is possible that the observed facilitation might indeed be due to the activation of a frequent letter combination rather than the activation of affixes.

4. Conclusion

The English writing system offers a number of morphological cues to readers. As shown above in Section 2, for example, final ‹s› can almost always be morphologically interpreted, given that the remaining graphemic word constitutes a well-formed stem. In a similar manner, final ‹ous› is the spelling of the derivational suffix; almost every word that ends with ‹ous› is an adjective. In this case, spelling basically serves as a part of speech tagging. Both the inflectional and the derivational examples extend to other suffixes; the demonstrated phenomena are not isolated cases in English.

Most crucial, however, is the fact that the corresponding phonological forms do not show the same degree of morphological transparency. Far from all words that end with /s/ or /z/, for example, bear the suffix ‹-s› (e.g. *lax*, *glimpse*, *bronze*), and only approximately half the words that end with /ɨs/ are adjectives (*service*, *bonus*, and *tennis* for example are not). The written forms are thus more informative with regard to morphological structure and/or category – they are morphographic.

What does that mean for studies that show affix stripping with written stimuli? Ultimately, this may be a special feature of the reading process, and not of

Uncorrected proofs - © John Benjamins Publishing Company

language processing in general. The reader, so to speak, just utilizes the complementary information provided in the written material, without necessarily using the same mechanisms in the processing of spoken language (of course, as we hypothesized above, the salience of an affix possibly hinges on a number of factors, and the story may be very different for any two given suffixes). After all we know about the non-isomorphic nature of written and spoken language, this is a distinct possibility.

This hypothesis could be tested in at least three ways, which were mentioned in the last section: First, future studies should investigate the difference between written and spoken language, possibly presenting "masked" auditory stimuli (provided that this technique taps the same processing as its visual counterpart). Second, researchers should take different distributional properties of final letter sequences into account, testing whether graphotactic sequences such as ‹et› cause priming while infrequent ones like ‹xy› do not. Third, they should contrast languages with richer morphographic systems (like English) and those with a more phonographic spelling (like, for example, Spanish).

Ultimately, this may also be a cautionary tale about the relationship between psycholinguistics and general linguistics: Without a thorough understanding of the language (and the modality!) at hand, conceived of as an abstract system, it may be very hard to interpret the psycholinguistic findings adequately.

Acknowledgments

This work was supported by the German Science Foundation (DFG) project "Prinzipien der Wortschreibung im Deutschen und Englischen" ('Principles of word spelling in German and English') and a fellowship within the Postdoc-Program of the German Academic Exchange Service (DAAD). Vera Heyer is now at the University of Braunschweig. We thank Harald Clahsen and João Veríssimo for comments on earlier drafts of the paper as well as Kathy Rastle and two anonymous reviewers for insightful comments during the review process.

References

Andrews, S., & Lo, S. (2013). Is morphological priming stronger for transparent than opaque words? It depends on individual differences in spelling and vocabulary. *Journal of Memory and Language*, 68, 279–296. doi:10.1016/j.jml.2012.12.001

Baayen, H., Piepenbrock, R., & Gulikers, L. (1995). *The CELEX lexical database (release 2)*. Philadelphia: Linguistic Data Consortium.

Bauer, L., Lieber, R., & Plag, I. (2013). *The Oxford Reference Guide to English Morphology*. Oxford: Oxford University Press. doi:10.1093/acprof:oso/9780198747062.001.0001

Uncorrected proofs - © John Benjamins Publishing Company

Berg, K. (2013). Graphemic alternations in English as a reflex of morphological structure. *Morphology*, 23, 387–408. doi:10.1007/s11525-013-9229-1

Berg, K. (in press). Sichtbare flexionsmorphologie im englischen und deutschen. der umgang mit variation in der schreibung von stämmen und affixen. To appear in: Fuhrhop, N., Szczepaniak, R. & Schmidt, K. (Eds.). *Sichtbare und hörbare Morphologie*.

Berg, K. (2016). Double consonants in English. Graphemic, morphological, prosodic and etymological determinants. *Reading and Writing*. doi:10.1007/s11145-015-9610-z

Berg, K. & Aronoff, M. (submitted). Self-organization in the spelling of English suffixes: The emergence of culture out of anarchy.

Berg, K., Buchmann, F., Dybiec, K., & Fuhrhop, N. (2014). Morphological spellings in English. *Written Language and Literacy*, 17, 282–307. doi:10.1075/wll.17.2.05ber

Bertram, R., Baayen, R. H., & Schreuder, R. (2000). Effects of family size for complex words. *Journal of Memory and Language*, 42, 390–405. doi:10.1006/jmla.1999.2681

Catach, N. (1980). *L'orthographe française. Traité théorique et pratique*. Paris: F. Nathan.

Crepaldi, D., Hemsworth, L., Davis, C. J., & Rastle, K. (2015). Masked suffix priming and morpheme positional constraints. *The Quarterly Journal of Experimental Psychology.* doi:10.1080/17470218.2015.1027713

Davis, C., Kim, J., & Barbaro, A. (2010). Masked speech priming: Neighborhood size matters. *Journal Acoustical Society of America*, 127, 2110–2113. doi:10.1121/1.3353116

Davis, M. H., & Rastle, K. (2010). Form and meaning in early morphological processing: Comment on Feldman, O'Connor, and Moscoso del Prado Martín (2009). *Psychonomic Bulletin & Review*, 17, 749–755. doi:10.3758/PBR.17.5.749

DeFrancis. J. (1984). *The Chinese language: Fact and fantasy*. Honolulu: University of Hawaii Press.

Diependaele, K., Sandra, D., & Grainger, J. (2005). Masked cross-modal morphological priming: Unravelling morpho-orthographic and morphosemantic influences in early word recognition. *Language and Cognitive Processes*, 20, 75–114. doi:10.1080/01690960444000197

Feldman, L. B., O'Connor, P. A., & Moscoso del Prado Martín, F. (2009). Early morphological processing is morphosemantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review*, 16, 684–691. doi:10.3758/PBR.16.4.684

Feldman, L. B., Milin, P., Cho, K. W., Moscoso del Prado Martín, F., & O'Connor, P. A. (2015). Must analysis of meaning follow analysis of form? A time course analysis. *Frontiers in Human Neuroscience*, 9, 111. doi:10.3389/fnhum.2015.00111

Flemming, E., & Johnson, S. (2007). Rosa's roses: Reduced vowels in American English. *Journal of the International Phonetic Association*, 37, 83–96. doi:10.1017/S0025100306002817

Forster, K. I., Mohan, K., & Hector, J. (2003). The mechanics of masked priming. In S. Kinoshita & S. J. Lupker (Eds.) *Masked priming. The state of the art*. (pp. 3–37). Hove (UK): Psychology Press.

Heyer, V. & Clahsen, H. (2015). Late bilinguals see a scan in scanner AND in scandal: dissecting formal overlap from morphological priming in the processing of derived nouns. *Bilingualism: Language and Cognition*, 18, 543–550. doi:10.1017/S1366728914000662

Katz, L. & Frost, R. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology and meaning* (pp. 67–84). Amsterdam: North-Holland. doi:10.1016/S0166-4115(08)62789-2

Uncorrected proofs - © John Benjamins Publishing Company

Kielar, A., Joanisse, M. F., & Hare, M. L. (2008). Priming English past tense verbs: Rules or statistics? *Journal of Memory and Language*, 58, 327–346. doi:10.1016/j.jml.2007.10.002

Kouider, S., & Dupoux, E. (2005). Subliminal speech priming. *Psychological Science*, 16, 617–625. doi:10.1111/j.1467-9280.2005.01584.x

Lavric, A., Elchlepp, H., & Ratle, K. (2012). Tracking hierarchical processing in morphological decomposition with brain potentials. *Journal of Experimental Psychology: Human Perception and Performance*, 38, 811–816. doi:10.1037/a0028960

Lázaro, M., Illera, V., & Sainz, J. (2015). The suffix priming effect: Further evidence for an early morpho-orthographic segmentation process independent of its semantic content. *The Quarterly Journal of Experimental Psychology*. doi:10.1080/17470218.2015.1031146

Longtin, C.-M., Segui, J., & Hallé, P. A. (2003). Morphological priming without morphological relationship. *Language and Cognitive Processes*, 18, 313–334. doi:10.1080/01690960244000036

Marchand, H. (1969). *The Categories and Types of Present-day English Word-Formation: A Synchronic-Diachronic Approach*, 2nd ed. Munich: Beck.

Marslen-Wilson, W. D. (2007). Morphological processes in language comprehension. In: M. G. Gaskell (Ed.), *Oxford handbook of psycholinguistics* (pp. 175–193). Oxford: Oxford University Press.

Marslen-Wilson, W. D., Bozic, M., & Randall, B. (2008). Early decomposition in visual word recognition: Dissociating morphology, form, and meaning. *Language and Cognitive Processes*, 23, 394–421. doi:10.1080/01690960701588004

Marslen-Wilson, W. D., Ford, M., Older, L., & Zhou, X. (1996). The combinatorial lexicon: Priming derivational affixes. Proceedings of the *Eighteenth Annual Conference of the Cognitive Science Society*, 223–227.

Marslen-Wilson, W. D., Tyler, L. K., Waksler, R., & Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological Review*, 101, 3–33. doi:10.1037/0033-295X.101.1.3

Marslen-Wilson, W., & Zhou, X. (1999). Abstractness, allomorphy, and lexical architecture. *Language and Cognitive Processes*, 14, 321–352. doi:10.1080/016909699386257

Meisenburg, T. (1998). Zur typologie von alphabetschriftsystemen anhand des parameters der Tiefe. *Linguistische Berichte*, 173, 43–64.

Otto, E. J. (2012). *Morphological processing in bilingual speakers of German and English*. Unpublished PhD Thesis. Royal Holloway, University of London, London.

Pastizzo, M. J., & Feldman, L. B. (2002). Discrepancies between orthographic and unrelated baselines in masked priming undermine a decompositional account of morphological facilitation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 244–249. doi:10.1037/0278-7393.28.1.244

Plag, I., Homann, J., & Kunter, G. (2015). Homophony and morphology: The acoustics of word-final S in English. *Journal of Linguistics*. doi:10.1017/S0022226715000183

Post, B., Marslen-Wilson, W. D., Randall, B., & Tyler, L. K. (2008). The processing of English regular inflections: Phonological cues to morphological structure. *Cognition*, 109, 1–17. doi:10.1016/j.cognition.2008.06.011

Rastle, K., & Davis, M. H. (2003). Reading morphologically complex words: Some thoughts from masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 279–305). New York: Psychology Press.

Rastle, K., & Davis, M. H. (2008). Morphological decomposition based on the analysis of orthography. *Language and Cognitive Processes*, 23, 942–971. doi:10.1080/01690960802069730

Uncorrected proofs - © John Benjamins Publishing Company

Rastle, K., Davis, M. H., Marslen-Wilson, W. D., & Tyler, L. K. (2000). Morphological and semantic effects in visual word recognition: A time-course study. *Language and Cognitive Processes*, 15, 507–537. doi:10.1080/01690960050119689

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, 11, 1090–1098. doi:10.3758/BF03196742

Sampson, G. (1985). *Writing systems. A linguistic introduction*. Stanford: Stanford University Press.

Segui, J., & Grainger, J. (1990). Priming word recognition with orthographic neighbors: Effects of relative prime-target frequency. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 65–76. doi:10.1037/0096-1523.16.1.65

Smolka, E., Preller, K. H., & Eulitz, C. (2014). 'Verstehen' ('understand') primes 'stehen' ('stand'): Morphological structure overrides semantic compositionality in the lexical representation of German complex verbs. *Journal of Memory and Language*, 72, 16-36. doi:10.1016/j.jml.2013.12.002

Smolka, E., Zwitserlood, P., & Rösler, F. (2007). Stem access in regular and irregular inflection: Evidence from German participles. *Journal of Memory and Language*, 57, 325-347. doi:10.1016/j.jml.2007.04.005

Sproat, R. (2010). *Language, technology, and society*. Oxford: Oxford University Press.

Taft, M., Castles, A., Davis, C., Lazendic, G. & Nguygen-Hoan, M. (2008). Automatic activation of orthography in spoken word recognition: Pseudohomograph priming. *Journal of Memory and Language*, 58, 366–379. doi:10.1016/j.jml.2007.11.002

Taft, M., & Nguyen-Hoan, M. (2010). A sticky stick? The locus of morphological representation in the lexicon. *Language and Cognitive Processes*, 25, 277–296. doi:10.1080/01690960903043261

Tyler, L. K., Randall, B., & Marslen-Wilson, W. D. (2002). Phonology and neuropsychology of the English past tense. *Neuropsychologia*, 4, 1154–1166. doi:10.1016/S0028-3932(01)00232-9

Ussishkin, A., Dawson, C. R., Wedel, A., & Schluter, K. (2015). Auditory masked priming in Maltese spoken word recognition. *Language, Cognition and Neuroscience*, 30, 1096–1115. doi:10.1080/23273798.2015.1005635

Corresponding address

Kristian Berg
Institut für Germanistik
Universität Oldenburg
26111 Oldenburg
Germany

kristian.berg@uni-oldenburg.de

Uncorrected proofs - © John Benjamins Publishing Company