Morphology in language comprehension, production and acquisition

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This Special Issue on Morphological Processing is based on the sixth MORphological PROcessing Conference (MOPROC), which was kept in June 2009 in Turku, Finland. The issue contains 13 articles by leading scholars in the field of morphological processing. These articles investigate the role morphemes play in language comprehension, production and acquisition. Specific questions relate to the time course with which morphemes come available, what factors facilitate their use, the role of orthographic and semantic transparency in complex word processing and how morphology should be incorporated in models of word processing. The papers in this issue provide a wealth of empirical results in several languages obtained with state-of-the-art experimental paradigms and will be an inspiration for further studies in morphological processing.

Keywords: Morphological processing; Comprehension; Production; Acquisition.

Is there a mouse in the mousetrap? Does darkness lead to happiness? Is there corn in the corner? Is there a fete in fetish? Would you find broth in your brother’s brothel? These are questions that make— to some extent— semantically sense, but for researchers interested in the role of morphology in word identification they make morphologically sense as well. In fact, these are questions that have made it to titles of recent scientific articles on morphological processing (Andrews, Miller, & Rayner, 2004; Duñabeitia, Perea, & Carreiras, 2008; McCormick, Rastle, & Davis, 2008; Rastle, Davis,
New, 2004) and/or to topics of heated debate (Feldman, O'Connor, & Martín, 2009). This Special Issue on Morphological Processing is based on the sixth MOrganization of PROcessing Conference (MOPROC) that was kept in Turku, Finland in June 2009 and hosted about 60 researchers with a firm interest in questions like these from a morphological point of view. The first time this conference was organised was in the south of France and since then five meetings of this series have been kept, which have resulted in four special issues on morphological processing with contributions by the participants of these meetings.

The current special issue on Morphological Processing contains 13 articles that provide answers on the questions presented above from different viewpoints, since it contains research on comprehension, production, and acquisition of morphology. Moreover, the research presented here is conducted in a number of languages with fundamentally different morphological systems. In the past, most research has been conducted in English and also in this issue English is well represented with 4 out of 13 studies examining English morphology. However, the special issue also contains a study in another West-Germanic language, namely Dutch; studies in the Romance languages of Spanish and Italian; studies in languages with very rich inflectional paradigms such as Greek, Polish, and Finnish; as well as studies in languages with nonconcatenative morphology such as Hebrew and Arabic. Moreover, the special issue contains studies on all three major morphological classes: Inflection, derivation, and compounding (see Table 1 for details).

From a morphological point of view, the playful questions presented above pertain to several scientific questions that are at the heart of morphological processing research. The questions are: (1) whether and under what circumstances morphological units are exploited in the course of polymorphemic word processing; (2) whether morphological units are also addressed when they are semantically disconnected from the word meaning; (3) what is the time course under which morphological information comes available; and finally, provided that morphological units are utilised in language processing, (4) how segmentation of the whole word into morphological units takes place and what is required for a successful segmentation? The current issue presents research that aims to find answers to questions like these. It also explores whether the activation of morphological units evokes the activation of whole morphological paradigms or networks, whether the word stem is the most prominent processing unit in a morphologically complex word, whether morphologically complex words are processed differently in sentence context than in isolation, and how normal and dyslectic children make use of or may struggle with morphological complexity when dealing with languages with rich inflectional morphology. In addition, several of the articles defend or challenge more or less specific
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<sup>a</sup>Visual lexical decision.

<sup>b</sup>Cross-case same-different task.
models of morphological processing. We will start with presenting one of the most prominent models of the past few years, namely the Automatic Morpho-Orthographic Segmentation and SUbsequent MOrpho-Semantic Analysis (AMOSSUMOSA) account (Longtin & Meunier, 2005; McCormick et al., 2008; Rastle et al., 2004). The reason for this is that this model accounts for many of the issues presented above and also because five articles in this special issue test assumptions put forth by this model.

TESTING THE AMOSSUMOSA ACCOUNT

The AMOSSUMOSA account holds that there is an early stage of polymorphemic (complex) word processing during which morphemes are extracted no matter the semantic relation of the constituents to the whole word. Semantics is involved in later stages of complex word processing, such that constituents that are semantically unrelated to the whole word are inhibited and do not affect complex word processing. We will first concentrate on the early morpho-orthographic segmentation stage in complex word processing.

The blindness to semantics at the early stage of processing implies that not only “dark” and “ness” are extracted from a transparent derivation such as “darkness”, but also “depart” and “ment” from an opaque derivation such as “department”. It even implies that “corn” and “er” are initially extracted from a pseudocomplex word such as “corner”, since the only requirement for the segmentation operation to be successful is that there are orthographic units that correspond to existing morphemes, and “corn” and “er” fulfil that requirement, even though they bear no semantic relation to “corner”. However, an additional assumption here is that the whole word form needs to be decomposable into morphemes for segmentation to be successful. In other words, if there are orthographic units in the word that do not correspond to morphemes, segmentation will not succeed. With respect to the examples presented in the beginning of this article, this means that “broth” will be extracted from “brother” but not from “brothel”, since “el” does not function as a suffix in English, in contrast to “er”. A final assumption of the model’s early processing stage is that morpho-orthographic segmentation is robust to common orthographic alternations. Therefore, a stem like “fete” will be extracted from “fetish”, since stem-final “e” is often deleted in the case of complex word formation. In other words, full orthographic transparency is not required for the segmentation process to be successful. All these assumptions have been derived from results obtained with masked priming in which a short exposure (40–50 ms) to a prime (e.g., mousetrap, darkness, corner, brother, and fetish) facilitates the subsequent processing of a target (mouse, dark,
corn, broth, and fete). Facilitation is not observed when there is only an orthographic relationship between the prime and the target (e.g., broth—broth, shovel—shove).

In the current issue there are four articles that challenge the assumptions of the early stage of the AMOSSUMOSA account. First, Rueckl and Rimzhim (2011 this issue) examined morphological processing of written words by combining the masked priming visual lexical decision paradigm with letter transposition manipulations. For monomorphemic words, letter transposition in the prime typically generates larger priming effects than letter replacement (e.g., JUGDE primes JUDGE more than JUPBE, see Perea & Lupker, 2003, 2004). This suggests that early orthographic letter coding is to some extent flexible in terms of coding specific letter positions. However, when morphologically complex words (e.g., boaster) are primed with primes where two letters spanning the morpheme boundary are transposed (boasetr), no priming effect is observed (Christianson, Johnson, & Rayner, 2005; Duñabeitia, Perea, & Carreiras, 2007). This suggests that the flexibility in coding letter position is restricted to morphological units. In line with the AMOSSUMOSA account, this also implicates that morpho-orthographic segmentation indeed occurs very early, co-occurring with or even before letter position assignment. Rueckl and Rimzhim report a series of five masked priming lexical decision experiments to further investigate the transposed letter effect with derived English words. One new aspect of their study was that in some of their experiments (Experiments 1–3) the roots (e.g., teach) of the derived-word primes (teacher) were used as targets. A letter transposition was introduced in the primes either within the word root (e.g., teahcer) or across the morpheme boundary (teaechr) and its effect on target processing was compared to the effect of primes with replaced letters (teakser). Perhaps surprisingly, they found a priming effect of similar size for the within-morpheme and across-morphemes conditions. Thus, unlike Christianson et al. (2005) or Duñabeitia et al. (2007), Rueckl and Rimzhim found no evidence that the letter transposition effect would disappear or become weaker when letter transposition takes place across the morpheme boundary. These results may be taken as evidence against the view of early morpho-orthographic segmentation during written word recognition as proposed by the AMOSSUMOSA account, even though the authors are cautious enough not to explicitly make this claim. Rueckl and Rimzhim consider a number of factors (see their Table 6) as possible determinants of the discrepancies between the results of their study and previous studies, but do not discern one single factor that may have triggered these discrepancies. However, they do point out that the list of factors they considered is not exhaustive.
Other evidence against the early morpho-orthographic segmentation account comes from Duñabeitia, Carreiras, Kinoshita, and Norris (2011 this issue). They also used letter transpositions in a masked priming paradigm, but instead of visual lexical decision they combined priming with a cross-case same-different matching task developed by Kinoshita and Norris (2009). In this task a reference stimulus is presented first (e.g., edge), after which a target stimulus is presented in a different case than the reference stimulus (EDGE). The task is to indicate with a button press whether the reference stimulus is identical to target stimulus independent of the case the word appears in (so edge and EDGE should be judged as identical). The task is shown to be sensitive to orthographic but not lexical processing (equal priming is obtained for words and nonwords)—a feature utilised by Duñabeitia et al. The cross-case same-different task was combined with the letter transposition paradigm, in which the two letters at a morpheme boundary are either transposed (e.g., mesoenro instead of mesonero; the study was conducted in Spanish) or replaced with formally similar letters (e.g., mesoasro instead of mesonero). An experimental trial began with a reference stimulus presented in lowercase for 1,000 ms, followed by a masked prime also presented in lowercase for 50 ms and then by the target in uppercase. In Experiment 1, transposed letter primes speeded up decision times in relation to replaced letter primes, which is in contrast to what Duñabeitia et al. (2007) found using the same stimuli in a standard lexical decision task. The priming effect was of similar magnitude for prefixed, suffixed, nonprefixed and nonsuffixed words. Similarly, Experiment 2 established a transposed letter priming effect of similar magnitude for polymorphemic, pseudo-polymorphemic and monomorphemic words—a finding in contrast to what has been observed previously using the lexical decision task (Longtin, Segui, & Halle, 2003; Rastle et al., 2004). Based on these results, the authors conclude that the “orthographically driven morphological decomposition process of polymorphemic words does not take place during the earliest stages of orthographic encoding”. (Duñabeitia et al., 2011 this issue, p. 518)

In future studies on morphology-based letter transposition effects, it would be good to expand the methodological repertoire beyond the standard masked priming paradigm. One ecologically valid approach to the study of printed language processing is to examine the eye fixation patterns occurring naturally during reading. In fact, letter transposition effects have been studied with eye-tracking (see Rayner, White, Johnson, & Liversedge, 2006; White, Johnson, Liversedge, & Rayner, 2008), although not in the context of morphological processing. An attractive option is to combine eye-tracking with the fast priming method (Sereno & Rayner, 1992), which is highly
similar to the masked priming method in the morphological processing studies.

Orfanidou, Davis, and Marslen-Wilson (2011 this issue) tested among other things how robust morpho-orthographic segmentation is to orthographic alternations in Greek. In order to do so, they used a standard masked priming visual lexical decision paradigm and included prime-target pairs that had a clear morphological and semantic relationship but an opaque orthographic relationship. Orthographic changes in the stem were more severe than in the experiments of McCormick, Rastle, and Davies (2009) in English, who found evidence for morpho-orthographic segmentation for primes in prime-target pairs with a missing “e” (adorable-adore), a shared “e” (lover-love) and a duplicated consonant (dropper-drop). Orfanidou et al. used prime-target pairs in which the orthographic relationship between prime and target differed from one another to a greater extent, such that the allomorphic variants were more suppletive in nature (poto-pino “drink-I drink”, figas-fevgo “fugitive-I leave”). Orfanidou et al. found no masked priming effects for these orthographically opaque primes, whereas solid priming effects were observed for orthographically transparent primes. McCormick et al. hypothesised that in case of mild orthographic opaqueness, the stem may be orthographically represented in an underspecified way. More specifically, they suggested that in these cases the morphological parser would segment the suffix from the stem (e.g., “able”), leaving a partial stem matching the underspecified orthographic representation (e.g., “ador”). The results of Orfanidou et al. imply that in the case of more severe orthographic opacity, allomorphic stems have their own orthographic representations and that at the early stages of complex word processing, activation of words containing such an allomorphic stem does not activate words containing its allomorphic relative.

Another observation along the same lines in this special issue comes from Morris, Porter, Grainger, and Holcomb (2011 this issue), who investigated priming effects of morphologically complex words and nonwords in English with a combination of masked priming and ERP recordings. In this paper, priming of a stem (e.g., “flex”) by a derived word (e.g., “flexible”), a complex nonword (e.g., “flexify”) and a simplex orthographically similar nonword (e.g., “flexint”) were compared. One of their main aims was to test the exhaustive morphological decomposition assumption made by the AMOS-SUMOSA model. An earlier study of Longtin and Meunier (2005) had found that even for nonwords, exhaustive morphological decomposition is required to find masked priming effects in French. More specifically, they found that a nonword containing a stem and a suffix (e.g., rapidifier = “quick + ify”) primed the stem (rapide = “quick”) to the same extent as the existing derived word (rapidement = “quickly”). This also held when
the nonword was completely uninterpretable (e.g., sportation). However, no priming effect could be observed when the prime only contained a stem but not a suffix (e.g., rapiduit, made of the root rapid- and a nonmorphological French ending -uit). In contrast to Longtin and Meunier, Morris et al. found that nonwords only including a stem (e.g., flexint) prime the stem (flex) equally well as real derived words (flexible) or complex nonwords with full morphological spanning (flexify). Their evoked brain potential results confirmed this pattern of priming effects by showing no differences in the early N250 component as a function of prime type. Morris et al. argue that the difference between the Longtin and Meunier study and their study is that they used nonwords in which the stem was fully contained (flexint-flex), whereas Longtin and Meunier used nonword primes for which the overlap with targets was not always complete (e.g., rapiduit-rapide, chambrage-chambre). It thus seems that a pseudostem is extracted from a nonword as long as the whole stem is present. At any rate, the Morris et al. study suggests that morpho-orthographic segmentation does not always depend on exhaustive morphological decomposition.

Paterson, Alcock, and Liversedge (2011 this issue) conducted a morphological priming study during sentence reading to test the AMOSSUMOSA hypotheses related to the later stages of complex word processing. The model claims that the later stages are dedicated to the morpho-semantic analysis, with one of the consequences being that semantically unrelated word pairs inhibit one another during the later processing stages of word processing. Paterson et al. used the same materials as Rastle et al. (2004) by including prime-target pairs that are orthographically, morphologically and semantically related (marshy-marsh), only orthographically and apparently morphologically related (in that the prime is exhaustively decomposable such as in secretary-secret) or only orthographically related (extract-extra). As in Rastle et al., the effect of the prime on target word processing was compared to the effect of length- and frequency-matched unrelated control words (thorny-marsh, obviously-secret, justify-extra). However, Paterson et al. included the prime-/control-target pairs in declarative sentences with 2–3 intervening words (the forest had a marshy/thorny path leading to a marsh where students studied wildlife), while registering readers’ eye movements. Earlier unmasked priming studies (either intra-modal or cross-modal) in which the prime is subject to conscious exposure showed that—unlike in masked priming studies—target word processing is only facilitated when the preceding prime is both morphologically and semantically related, in line with the hypothesis that later stages of complex word processing involve semantics. The results of Paterson et al. are in line with these results: all fixation duration measures (first fixation, single fixation, gaze and total fixation duration) show that target word processing is only facilitated when there is a clear semantic
relationship between prime and target (in comparison to the unrelated control condition). It is important that the pattern of results found in unmasked priming studies (often in combination with lexical decision) is supported by the results of a method that is ecologically more valid. The results of this eye movement study tie in with the results of Experiment 2 of Orfanidou et al., who showed that visual lexical decisions preceded by (unmasked) delayed primes are also modulated by semantic opacity. That is, in their Experiment 2 target responses were facilitated by morphologically and semantically transparent primes but not by semantically unrelated primes that share an apparent morphological relationship with its target. This pattern was not affected by the orthographic relationship between prime and target, with equivalent priming for orthographically transparent and opaque pairs.

Coming back to Paterson et al. (2011 this issue), an intriguing aspect of this study is that a pure orthographic priming effect was obtained in two other measures. That is, skipping rates of target words followed by primes were higher than skipping rates of target words followed by control words, no matter the semantic relationship between prime and target. In addition, there were more regressions back from the posttarget region when targets had followed primes rather than controls. This increased regression rate was also present when the target word was not skipped. These effects are explained as a possible misidentification of words due to earlier activation of orthographically similar but lexically different words. Finally, Paterson et al. report data suggesting that morphology may have a role to play in the recovery of these misidentifications, as both the morphologically related and the apparently morphologically related conditions did not elicit longer posttarget first pass reading times than their controls, whereas the only orthographically related condition did. This points to a possibility that an apparent morphological relationship is reinstated in case of a processing difficulty caused by an initial misidentification of a word.

The Paterson et al. and the Orfanidou et al. study (Experiment 2) indicate that in line with the AMOSSUMOSA account, the use of morphological information in later stages of complex word processing depends on semantic transparency. However, as reviewed above, there is controversy concerning the early stage of morpheme extraction. The studies of Rueckl et al., Duñabeitia et al., Morris et al. and Experiment 1 of Orfanidou et al. indicate that the morpho-orthographic segmentation hypothesis as proposed by Rastle et al. does not hold under all circumstances. The former two studies imply that either morpho-orthographic segmentation is not as automatic and swift as has been hypothesised or that it may not take place at all. The third study showed that morphologically related but orthographically opaque complex word forms do not prime each other under masked priming conditions, implying that such word forms are not sharing an
(underspecified) orthographic representation in the mental lexicon. The fourth study showed that a stem incorporated in a nonword may be detected even though the complete letter string cannot be exhaustively segmented into morphological units.

One of the limitations of the AMOSSUMOSA account is that it neglects specific morphological and whole-word properties that may modify the ease with which a morphologically complex word can be segmented into its constituent morphemes. Nevertheless, there is a host of studies demonstrating that the role of morphology is more or less prominent depending on the properties of the morphological constituents and the whole word (e.g., affix length and affix productivity, see Ford, Davis, & Marslen-Wilson, 2010; Kuperman, Bertram, & Baayen, 2010; Laudanna, Burani, & Cermele, 1994; Laudanna & Burani, 1995; constituent and whole-word frequency, see Alegre & Gordon, 1999; Colé, Segui, & Taft, 1997; or word length, see Bertram & Hyönä, 2003). To summarise these studies, one could say that the role of morphological units is more prominent when these units are highly salient. Thus, in case a constituent morpheme is frequent, long, and productive, and the whole word containing such constituent morphemes is long and infrequent, morphological effects are likely to emerge, as word segmentation into constituent morphemes is swift. In this light, it may be that for instance Rueckl and Rimzhim failed to find evidence for morpho-orthographic segmentation because they used “too frequent” words (their derivations were much more frequent than those of Rastle et al., 2004) or too unproductive suffixes.

THE ROLE OF MORPHOLOGICAL PROPERTIES IN COMPLEX WORD COMPREHENSION

There are two studies in this special issue with a special focus on the role of morphological properties in complex word comprehension. Boudelaa and Marslen-Wilson (2011 this issue) report two priming studies in Arabic, a language with nonconcatenative morphology, in which they orthogonally manipulated the productivity of the root and word pattern. In a nonconcatenative language like Arabic, a derivational root is distributed across the entire word form so that the consonants comprising the root (typically three) are not positioned next to each other but interwoven with a word pattern that creates variations on the root’s meaning and conveys grammatical information. The specific question Boudelaa and Marslen-Wilson asked was whether word pattern priming can be observed as a function of its own productivity or whether it depends on the productivity of the root. They calculated the productivity of a particular morpheme (e.g., dark) by counting how often that specific morpheme has been involved in word formation either as a
derivation (as in darkness) or a compound word constituent (as in darkroom). This type of productivity has become prominent under the label “family size” (Baayen, Lieber, & Schreuder, 1997; Schreuder & Baayen, 1997). In general, regardless of its productivity, the consonantal root may be a more prominent processing unit, as it is fully specified in Arabic orthography, whereas the intertwined word pattern is only partially specified (only long vowels and consonants in the word pattern are orthographically expressed). In Experiment 1, Boudelaa and Marslen-Wilson found with the masked priming paradigm that word pattern priming can only be observed in the context of a productive root. Word primes with productive and unproductive word patterns primed target words with a different consonantal root but the same word pattern only, when the consonantal root was productive and not when it was unproductive. In Experiment 2, they tested the same materials in a cross-modal priming task. In this case, the primes are out there for conscious perception, but most importantly, word patterns are fully specified in the prime since the prime appears in the auditory modality. If underspecification of the word pattern would have caused the effect in Experiment 1, one would expect a more prominent role for the productivity of the word pattern in the cross-modal priming paradigm. However, as in Experiment 1, the results showed that the priming effect was determined entirely by the productivity of the root. That is, word pattern priming only appeared in the context of a productive root. This indicates the importance of the root in driving on-line decomposition of Arabic surface forms into their constituent morphemes. The authors cite previous and upcoming studies to argue that unproductive roots do prime themselves, so it is not the case that words with an unproductive root are not decomposed. However, the current results suggest that word pattern extraction is dependent on the extraction of the root and it seems that information on the unproductive roots comes available too late for word patterns to be extracted to the extent that they have a facilitative role in priming.

Juhasz and Berkowitz (2011 this issue) investigated the role of family size in complex word recognition by means of a naming, visual lexical decision, and an eye movement experiment. More specifically, they investigated the role of the family size of the left constituent in the recognition of English concatenated compounds. Left constituent family size is defined as the number of derivational and compound descendants that can be formed with a given left constituent (cf. Schreuder & Baayen, 1997; e.g., the word aircraft has a rather large left constituent family size, since next to aircraft there are family members such as airport, airtight, air force, airhostess, etc.). Previous studies in English have found mixed evidence for a first constituent frequency effect and Juhasz (2008) has been attributing that to family size as a possible confound. However, the present study that revisits the previous ones shows
that family size has not been a confounding factor there. Nevertheless, all experiments in the current study showed that there was a facilitative role for family size, with shorter naming and lexical decision latencies as well as shorter gaze durations for compounds with a large left constituent family size than for those with a small family size (see also Kuperman, Bertram, & Baayen, 2008; Kuperman, Schreuder, Bertram, & Baayen, 2009, for a similar effect in Finnish and Dutch). With respect to the eye movement experiment, Juhasz and Berkowitz observed that the family size effect was quite early, indicating that morphological families are activated early on in the processing stream before full-form identification. Interestingly, the facilitation driven by family size was attenuated for compounds with a large number of higher-frequency family members (HFFM). This implies that a higher-frequency compound like *airport* hinders the recognition of its lower-frequency family member *aircraft*. Kuperman et al. (2008, 2009) suggest that the effect of morphological family size may derive from the reader’s specific experience with parsing out and recognising a specific morphemic constituent as part of a larger word. In the case of complex words whose left and/or right morphemic constituent possess a large family, the reader may have ample experience with parsing out those specific constituents from a morphologically complex word. This type of reasoning goes against the AMOSSUMOSA account, which holds that segmentation should be unaffected by factors such as family size or productivity. The results of Juhasz and Berkowitz with respect to HFFM are also interesting in that they imply that family size does not only reflect “practice with segmentation”, but also that other lexical candidates morphologically related to the target word become really activated during the recognition process.

**THE ROLE OF MORPHOLOGY IN WORD PRODUCTION**

Turning from comprehension to production, we find similar kinds of ideas in the study of Bien, Baayen, and Levelt (2011 this issue) as in the Juhasz and Berkowitz study (2011 this issue). Bien et al. employed a position-response association task to elicit production of deverbal adjectives (Experiment 1) and inflected verbs (Experiment 2) in Dutch. Mixed-effects modelling was used to determine the factors that affect the production of these morphologically complex words. Bien et al. set out to test three different accounts, the so-called full-listing account, which assumes that morphologically complex words are fully listed at the word-form level (e.g., Butterworth, 1983; Janssen, Bi, & Caramazza, 2008), the decomposition account (e.g., Levelt, 2001; Levelt, Roelofs, & Meyer, 1999), which proposes that the word-form level contains only morphemes, and that these morphemes are accessed during the production of a morphologically complex word (this is akin to the
AMOSSUMOSA account in comprehension), and a paradigmatic account (also called structured storage account), which suggests a lexicon in which word forms are interlinked and organised in paradigms, such that they influence each other in production. They found that production of deverbal adjectives was mainly determined by the cumulative stem frequency, supporting the decomposition account. However, for inflections there was an inhibitory effect of inflectional entropy and a nonlinear effect of lemma frequency. Especially the former effect supports the paradigmatic relation/structured storage account. It indicates that speakers have most difficulties in producing an inflectional form for which all the inflectional forms are realised in the paradigm and occur with similar frequency (e.g., “works” would be hard to produce if “works”, “worked”, and “working” all appear equally often in English). In other words, if equally strong inflectional candidates compete with each other, it becomes hard to choose one over the others. This finding is akin to the HFFM-effect of Juhasz and Berkowitz (2011 this issue) observed in comprehension.

For Bien et al. (2011 this issue) the inhibitory effect of inflectional entropy lends support to the position that inflectional verb forms are not islands that can be produced independently, but are instead forms with links to morphologically related word forms. Bien et al. hold that derivational paradigms are less important, since they—in Dutch at least—only contain two forms, a singular and a plural, whereas the inflectional paradigm is much richer (seven forms). However, other evidence for paradigmatic relations is found in both Experiments 1 and 2 on a phonological level with effects for both cohort entropy and position-specific neighbourhood density. This is taken as further evidence for the view that “the word-form level does not contain full listings or strictly separated morphemes but morphemes with links to phonologically and—in case of inflected verbs—morphologically related word forms”.

Another study in this special issue investigating the role of morphemes in word production is the study of Deutsch and Meir (2011 this issue) conducted in Hebrew. Similar to Arabic, Hebrew represents a language with nonconcatenative morphology in which derivational roots are intertwined with word patterns. Thus, the process of morphological composition in word production may be complicated by the fact that, as Deutsch and Meir put it, “no simple linear principle for applying the various morphemes sequentially seems plausible” (p. 721). Language processes involved in word production were studied using the picture-word interference paradigm (Schriefers, Meyer, & Levelt, 1990), in which spoken distracter words that were phonologically, morphologically or semantically related to the to-be-named picture are presented with different stimulus onset asynchronies (SOAs; i.e., the distracter is presented prior to, simultaneously with, or after
the target picture). The underlying idea in this paradigm is that if the related distracter word interferes with or facilitates the ongoing process of preparing to name aloud a picture, naming latency will be delayed or speeded up in comparison to an unrelated baseline condition. By varying the SOA, the researcher is in a position to tap into the time course of different processing components (activating semantic, morphological, and phonological information) relevant to successful task performance. The results demonstrated a facilitatory effect for morphologically related distracters across all SOAs (from −200 ms prior to target onset to +300 ms following target onset). On the other hand, semantic relatedness inhibited naming when the distracter word was presented prior to or simultaneously with the target picture. Finally, phonological relatedness between the distracter and the target brought about a facilitation effect starting at SOA −100 ms. Deutsch and Meir argue that the observed morphological effect reflects an autonomous morphological process distinct from the semantic and phonological effects. The semantic effect differs from the morphological effect both in its nature (inhibition versus facilitation) and its time course, and the phonological effect differs from the morphological effect in its time course, emerging later than the morphological effect. On the basis of these results and those obtained earlier for visual word recognition in Hebrew, Deutsch and Meir put forth a model that assumes a common lexical organisation for perception and production, namely that “words derived from the same root are clustered around a shared root unit” (p. 735). In word production in Hebrew, the mapping of abstract lemma representations onto their corresponding phonological structures is assumed to involve the activation of word roots connected to the lemma representations. This model—even though proposed to accommodate findings in Hebrew—is quite similar to other production models (see Levelt et al., 1999) and is also in line with the AMOSSUMOSA account discussed earlier, but is silent about the possibility of morphological paradigms being involved in word production as proposed by Bien et al. (2011 this issue).

De Martino, Bracco, and Laudanna (2011 this issue) combined production and comprehension tasks to investigate the role of gender information in processing inflected nouns in Italian. More specifically, they wanted to investigate whether gender information is automatically accessed on the basis of the suffix, with singular nouns ending in -o pointing to masculine (since the vast majority of masculine nouns ends with the suffix -o) and singular nouns ending in -a pointing to feminine nouns (since the vast majority of feminine nouns ends with the suffix -a). If this is the case, exceptionally occurring masculine singular nouns ending in “-a” like problema (“problem”) may be hard to process, since the gender information provided by the suffix (feminine) is in conflict with the actual gender of the noun (masculine).
De Martino et al. compared the processing of regular feminine singular nouns like *piscina* (“swimming pool”) with the processing of irregular masculine singular nouns like *problema* in a naming, visual lexical decision, and an on-line inflection task (in which plural forms like *problemi* were used to prompt the production of single forms like *problema*). De Martino et al. found in all three experiments shorter response latencies and/or lower error rates for regular feminine nouns like piscina than for irregular masculine nouns like problema. In order to ensure that the difference was not triggered by gender as such they conducted the same three experiments with regular plural feminine and regular plural masculine forms. The fact that they did not find any differences between nouns of different gender in any of these experiments assured them that feminine nouns are not categorically processed faster than masculine ones. Consequently, the delay in processing irregular masculine singular nouns in comparison to feminine ones was ascribed to the conflict between the orthographic-phonological information displayed in the gender suffix pointing to a feminine noun and the actual gender of the noun. The authors point out that the effect was observed for Italian nouns without syntactic context (for instance, articles) and in tasks that do not require explicit processing of gender information like lexical decision and word naming. They discuss their findings in the context of other results and models of word production rather than in the context of word comprehension. They argue that, taken together, the results go against the claims of Roelofs, Meyer, and Levelt (1998), who hold that the retrieval of noun gender is called for only within a syntactic context, for instance when agreement should be established between a noun and its modifier or article. However, the results are in line with those of Cubelli, Lotto, Paolieri, Girelli, and Job (2005), who claim that gender information does affect single noun processing in Italian, because the selection of semantic and syntactic representations takes place before the selection of the orthographic–phonological form. This leads to competition between the selected rule-based suffix for the masculine gender at the syntactic level (-o) and the selection of the phonological affix (-a) at a later stage. A similar kind of competition mechanism is proposed by the independent network model of Caramazza (1997).

THE ROLE OF MORPHOLOGY IN LANGUAGE ACQUISITION

In addition to the seven studies with the main focus on comprehension and the three with the main focus on production in adults, the special issue contains three studies that deal with the role of morphology in language acquisition. Traficante, Marcolini, Luci, Zoccolotti, and Burani (2011 this issue) tested whether skilled and dyslectic sixth graders take benefit from
morphological structure in reading aloud pseudowords. More specifically, they investigated the relative roles of roots and suffixes in morphological processing by exposing their young participants to pseudowords with different morphological structure. The materials were the same as those used by Burani, Arduino, and Marcolini (2006, Experiment 3) for adults and consisted of pseudowords containing a root and a suffix, a root and a nonsuffix, a nonroot and a suffix, and a nonroot and a nonsuffix. Burani et al. (2006) found in both response latencies and accuracy rates that adults took advantage of the presence of both the root and the suffix in naming pseudowords. The current results showed that—similarly to Burani et al. (2006)—a root in the initial part of the stimulus led to faster and more accurate naming than a similar nonroot letter cluster, for both skilled and dyslectic young children. The subsequent regression analyses revealed that the effect of root was strong and significant over and above the effect of the root bigram frequency. However, with respect to the effect of suffix, the present data for young readers were partially different from those of adults (Burani et al., 2006), since the presence of a suffix only affected response accuracy, but not naming latency. The authors hypothesise that a more pronounced effect for the root than for the suffix may point to a more prominent role of the root in decomposing suffixed words, which may be driven by the root being in the first position (cf. the visual acuity hypothesis of Bertram & Hyönä, 2003). At any rate, the authors hold that “the present results can be explained with reference to a morphologically decomposed lexicon, in which both roots and suffixes are stored” (Traficante et al., 2011 this issue, p. 790) and that “accordingly, they are compatible with both sublexical (Taft, 1994) and dual route (Burani & Caramazza, 1987; Schreuder & Baayen, 1995) models” (Traficante et al., 2011 this issue, p. 790). The dual-route models refer here to models claiming that access to morphologically complex words is attempted both by a morphological decomposition route and a whole-word route and that specific lexical properties, such as word and/or morpheme frequency, dictate which route will win the race.

Kidd and Kirjavainen (2011 this issue) studied the acquisition of past tense morphology in Finnish-speaking preschool children. Their main aim was to test two competing theories of the acquisition of past tense morphology that diverge somewhat from the morphological models presented above in that they postulate specific routes to different memory systems. Yet one of them, the dual route model of Ullman (2004), is known under the same name as one of the models presented in the previous paragraph. According to Ullman’s dual route model, a rule-based route is supported by procedural memory and utilised in acquiring regularly inflected verb forms, whereas an associative route supported by declarative (semantic)
memory is used in the acquisition of irregular verb forms. On the other hand, according to single route approaches (e.g., Plunkett & Marchman, 1991) the acquisition of both regular and irregular past tense morphology is based on the same associative learning mechanism. In this approach, “morphological structure is conceived as an emergent property of the connections between items in the lexical network” (Kidd & Kirjavainen, 2011 this issue, p. 798). Kidd and Kirjavainen (2011 this issue) investigated the acquisition of past tense forms in the very complex verbal morphology of Finnish. Each verb clearly has over 100 forms (to be precise, in Finnish, nondefective verb paradigms carry 850 surface core forms, and it explodes to 12,000–18,000 forms when clitics are included), in comparison to four different surface forms of English verbs. Finnish has two past tense allomorphs and adding those to the stem introduces a stem change in some verbs. Moreover, the stem changes may be more or less regular. Four- to six-year-old children’s ability to produce past tense forms with a productive or a semi-productive suffix was tested in an elicitation task including both real and novel verbs. Moreover, a test of procedural and declarative memory, as well as a test of receptive vocabulary and nonverbal ability, was administered to the children.

In order to test the dual route account, Kidd and Kirjavainen (2011 this issue) correlated performance on the procedural memory test with the children’s ability to produce regular-like past tense forms, and the performance on the declarative memory test with the ability to produce irregular-like forms. The results showed that procedural memory did not correlate significantly with any measure of past tense production, which is inconsistent with the account. However, as predicted by Ullman’s (2004) dual-route model, declarative memory correlated with children’s performance on irregular-like past tense forms. The single route approach predicts that declarative memory predicts vocabulary size, which in turn predicts performance on all verb types. The observed pattern of correlations was fully consistent with the predictions of the single route account. Establishing a significant correlation between vocabulary knowledge (declarative memory) and past-tense formation on novel verbs provides further support for the model. In general, the results reported by Kidd and Kirjavainen provide support for a close relationship between lexical and grammatical development among preschool children.

Finally, Krajewski et al. (2011 this issue) also tested predictions derived from the dual route and single route theories on the acquisition of inflectional morphology. The study was conducted with Polish-speaking 2- to 3-year-old children. In two experiments, children’s ability to switch from one inflectional form of a noun to another was examined in a nonce word elicitation task. Similarly to Finnish studied by Kidd and Kirjavainen (2011 this issue), Polish noun declensions offer interesting avenues for the study of
the acquisition of inflectional morphology, as a considerable number of inflectional forms exists for each noun with a substantial amount of allomorphic variation and stem alternations as well as nontrivial rules for governing choices between inflectional forms.

In a variant of the wug test (Berko, 1958), Polish children’s ability to produce a correct inflectional form from another inflectional form was tested. The source forms presented to the children were all inflected (unlike in the original version of the test), as all nouns in Polish are inflected (i.e., no uninflected base form exists). In Experiment 1, the source forms of nonce words were varied to see how it affects the production of the target form (always the genitive singular with a few possible endings). The pattern of results suggests that similarity in form between the source and target rather than the frequency of the source form affects children’s ability to switch from one inflectional form to another. In Experiment 2, the target form was changed to the nominative, but the source forms remained the same as in Experiment 1. Again, the source form influenced the production of the target form. Moreover, the frequency of the target form seemed irrelevant, as the overall performance was equally good with the genitive (Experiment 1) and the nominative case (Experiment 2), despite the fact that nominative is clearly more frequent than genitive. In general, identifying a source form and producing a target form appear to be intrinsically related (i.e., not carried out via two independent mechanisms). The pattern of data is interpreted to support a usage-based (single route) rather than rule-based (dual route) approach to the acquisition of inflectional morphology. Krajewski et al. speculate that “switching between inflections is underpinned by some sort of emergent generalisations based on a pairing of form and meaning” (Krajewski et al., 2011 this issue, p. 854). On the other hand, the lack of frequency effects poses a problem also to the usage-based approach.

CONCLUSIONS

Altogether, the 13 articles comprising the special issue offer answers on the questions stated in the beginning. They provide evidence that (1) morphological units are exploited in the course of polymorphemic word processing; (2) under some circumstances the word stem or root comes more quickly available than the suffix (or word pattern in nonconcatenative languages); (3) productive morphemic units are more easily available for the processing system and/or such units are more easily segmented out of the whole letter string than less productive units; (4) activation of morphological units evokes activation of morphological paradigms or networks, which may be beneficial or disruptive to processing depending on the specific properties of the morphological relatives in the paradigm; (5) there may be a specific role for
morphology in sentence comprehension, related to the recovery of initially misidentified words; and (6) both normal and dyslectic children exploit morphological structure and morphological relationships between words in order to deal with novel words and to increase the size of their lexicon.

It may be clear from the above that there is no single theoretical account of morphological processing that accommodates all or even most of the results that have been obtained in comprehension, production, or acquisition. All the morphological processing models proposed or discussed in this issue or elsewhere have a common feature in that they all assume that the lexicon is organised in a morphologically motivated manner and that morphological units have a functional role to play in the processing of complex words. Apart from that, they differ in terms of the specific architecture of the lexicon, with respect to the time course with which morphological information comes available, the role of morphological relatives, whether morphological units emerge from consistent linking between form and meaning, and so on. It is of course unthinkable that a single model would be able to account for all comprehension, production and acquisition data in all languages. Yet we think that it is important that models (1) take seriously into account factors that influence morphological processing across different languages; (2) should consider several factors at the same time and make use of the possibilities of new statistical techniques; (3) base their architecture on the results of different experimental methods; and (4) should be developed from mere verbal description towards computational implementations. We think that the current issue includes important insights for model development along these lines.

Elaborating on the first issue, we suggest that every model should incorporate in its architecture the factors that have established themselves as relevant factors in morphological processing. Perhaps the most relevant factor in this respect is productivity of morphological constituents. Productivity can be defined and calculated in several ways (see Baayen, 1992; Boudelaa & Marslen-Wilson, 2011 this issue, who equate productivity with family size), but the underlying principle always pertains to the idea that morphemes vary in the extent to which they can be used in word formation. Practically all morphological processing studies that have manipulated this factor in one way or another have demonstrated that productive morphemes are more likely to have an active role in complex word processing than unproductive morphemes (e.g., Baayen, 1994; Bertram, Laine, & Karvinen, 1999; Bertram, Schreuder, & Baayen, 2000; Boudelaa & Marslen-Wilson, 2011 this issue; De Jong, Schreuder, & Baayen, 2000; Ford et al., 2010; Krott & Nicoladis, 2005; Laudanna et al., 1994; Laudanna & Burani, 1995; Pastizzo & Feldman, 2004; Vannest & Boland, 1999). Hence we suggest that
any morphological processing model should be able to account for the productivity effect. To their credit, a successor of the AMOSSUMOSA model (proposed by Crepaldi, Rastle, Coltheart, & Nickels, 2010 to accommodate new masked priming findings) does incorporate the notion that productive morphemes are represented at the level of morpho-orthographic representations, while “rare morphemes might not be represented at this level” (p. 95). As noted earlier, there may be additional factors, such as affix length, morpheme frequency, and whole word frequency (and their relations), that also need to be accounted for by any morphological processing model.

This brings us to our second point that in empirical studies of morphological processing, several factors should be simultaneously considered more often than what is typically the case. In many studies, one or at most two factors are studied at the same time. Yet, it may well be that certain factors interact with each other to produce nonadditive effects. For example, it may well be that morphemic productivity plays a larger role in processing infrequent words and/or words containing affixes that are of considerable length. If one does not take these kinds of possibilities into consideration, it may well be that the results diverge simply because investigations have been done using materials originating from different segments of the lexical space. For instance, as noted earlier, it may be that Rueckl and Rimzhim (2011 this issue) failed to find effects of early morpho-orthographic segmentation simply because the chosen target items were more frequent than in previous studies and/or because the selected suffixes were too unproductive. One problem many researchers have struggled with is one posed by the limitations of the factorial design. For practical reasons, factorial designs often do not allow to manipulate more than two factors at a time, while controlling for all possible other relevant factors. Inspired by Baayen (see e.g., Baayen, 2008; Baayen, Davidson, & Bates, 2008), a growing number of morphological processing researchers has exchanged factorial designs and analyses by traditional ANOVAs for regression designs and step-wise multiple regression mixed-effects modelling with participants and items as crossed random effects. These models allow one to consider many predictors simultaneously and to test the relative strength of their effects over and beyond the effects of other variables. In this issue, there are several studies that have chosen this option. In general, we think that models of morphological processing will be much more complex once more efforts are made to cover the multidynamic nature of complex word processing.

Third, it is important to use different experimental methods in order to investigate the role of morphology in complex word processing. It is naturally the case that not all paradigms tap into the same levels of processing. However, this is an advantage rather than a hindrance in acquiring a more complete
picture of complex word processing. For instance, in this issue Duñabeitia et al. showed that the transposition letter effect across morpheme boundaries can be obtained in a cross-case same-different task with masked priming, while the effect disappears in a masked priming visual lexical decision paradigm. This discrepancy allowed them to generate more specific conclusions with respect to the morpho-orthographic segmentation stage. Naturally, results may converge across paradigms as well. In this issue, Paterson et al. showed for instance that the overt priming effects obtained in lexical decision can be obtained with eye movement measures for target words presented in sentence context. Similarly, Juhasz and Berkowitz (2011 this issue) showed that family size effects appeared across three different tasks. The fact that family size effects were rather robust across tasks allowed them to speculate on the time course of these effects. So we strongly favour the use of different experimental paradigms in order to ensure that morphological effects are real and not idiosyncratic to the specific paradigms used. In that sense, it is somewhat worrying that current theorising in morphological processing leans heavily on the masked priming paradigm in combination with single word recognition tasks. For instance, the AMOSSU-MOSA account is mainly built upon evidence derived from this paradigm. This is problematic for several reasons. Outside the laboratory, words are most often read in context; thus, single word tasks are blind to the ways morphological processes may interact with contextual aspects. There are two main differences between single word recognition tasks and normal reading. First, in sentence context, a word is preprocessed for its length and the initial letters before the eyes fixate on it. Second, readers may make use of the context in order to predict syntactic or semantic properties of upcoming words (see Rayner, 1998, for a survey). In order to examine the extent to which masked priming results generalise to normal reading, one could combine readers’ eye-tracking with the fast priming method (Sereno & Rayner, 1992), which is highly similar to the masked priming technique.

Moreover, (pseudo)morphological effects with masked priming are often taken to indicate that the segmentation process is fast, automatic and effortless, since a prime presented for only 40 ms is enough to facilitate the processing of its morphological relatives. However, it should be noted that the neural pathways that need to be traversed before morphological segmentation can take place would make such quick segmentation physiologically impossible. In other words, whereas 40 ms presentation time is apparently enough to get the prime into the (visual) system, it will require another unknown amount of milliseconds before segmentation is completed. It may therefore be important to combine masked priming with other experimental paradigms such as evoked brain potentials (see Morris et al., 2011 this issue) or eye movements in reading (see our earlier suggestion) that give insight into the time course of different processing stages. Note that the
example with masked priming is mentioned to illustrate that it may be important to pursue a multi-paradigmatic approach or to at least incorporate the findings obtained with different paradigms into the models of morphological processing.

Finally, in the previous special issue on morphological processing the editors concluded that more complex computational models are needed to leave old dichotomies behind. We also feel that such models should be developed in order to account for the diversity of results that is found across studies. To our minds, this issue has shown that the role morphology plays in complex word processing is dependent on (the interplay of) several factors, and simple verbal models—no matter whether they are decomposition, dual route, full listing, or paradigmatic models—do not capture these dynamics. Hence computational implementations are needed to test and develop the assumptions laid down in the verbal models.

All in all, the papers in this issue provide a wealth of empirical results in several languages obtained with state-of-the-art experimental paradigms. We hope that they will be an inspiration for further studies in morphological processing as much as we—facing the coming winter in Finland—hope that there is happiness in darkness.

REFERENCES


