Prefixed Words in Morphological Processing and Morphological Impairments

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Preface

The present doctoral project was carried out as part of the International Ph.D. Program for Experimental and Clinical Linguistics (IECL) at the University of Potsdam, Germany. Most of the laboratory work was conducted at the Potsdam Research Institute for Multilingualism (PRIM) and the University of Potsdam and supported by an Alexander-von-Humboldt Professorship awarded to Harald Clahsen and the PRIM.

The thesis is written in English and it is presented as cumulative Ph.D. thesis at the University of Potsdam, Faculty of Human Sciences. It includes eight chapters. In Chapter 1, I present the main topic of the thesis and the research questions underlying the experimental work I conducted. Chapter 2 provides an overview of the four publications included in the thesis. This is followed by four empirical chapters (3 to 6) consisting of four first-authored manuscripts. The first three manuscripts have been published in international peer-reviewed journals of the field, while the fourth manuscript is currently under review. Chapter 7 provides a summary and discussion of the findings of the four experimental chapters. Finally, Chapter 8 is dedicated to general conclusions, limitations of the present work, and the future perspectives opened by the present dissertation.

Acknowledgements

The content of the present thesis is the result of years of work during which I was advised, encouraged, inspired, by many people I was lucky enough to encounter during this journey.

I am extremely grateful to my first supervisor Harald Clahsen for believing in my potential, supporting me financially even when this was not taken for granted, always being available to discuss my work, my progress, or my future, for providing enlightening but also direct feedback when this was required, and also for warning me about my perfectionism when he noticed that this was getting out of control.

In the past years, I have been part of a psycholinguistics team whose members, in one way or the other, all contributed to this work. Among them, I am especially grateful to Gunnar Jacob, the first person I had the chance to work with at PRIM, who strongly believed in me and encouraged me during the initial phase of my PhD, when I felt literally lost and disoriented. This thesis would have not been possible without the guidance of João Veríssimo, not only for the time he dedicated to teaching me statistics and discussing my questions, but also for being a source of inspiration for what kind of researcher and mentor I want to be.

For the part of the work on acquired language disorders, I am grateful to Frank Burchert, the second supervisor of my thesis, who gave me the opportunity to get enrolled as a PhD student in Potsdam and encouraged me to get to know the other people working on aphasia in our department. The contribution of Carlo Semenza to this part of the thesis has been crucial. I'm particularly grateful for his incredibly quick responses despite the distance, and the constant encouragement during the preparation and revisions of our manuscripts. I'm also immensely grateful to the persons with aphasia who took part in my experiments, who donated me so many smiles and so much good mood, and taught me so much about the value of life and of finding happiness and beauty in small every-day situations.

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'Back-home', but still on the academic side, I am grateful to Savina Raynaud, the supervisor of my Master's thesis, for always caring about staying in touch and feeling involved in my academic development. I am also particularly grateful for her constant effort in trying to have people who work on language from different perspectives communicate to each other.

My parents provided me with all the strength and motivation (and stubbornness) I am equipped with. I am grateful to them, and to my sister Claudia, for their blind confidence that I am doing a great job, despite the fact that I hate talking about myself. The intellectually lively environment the three of them contributed to when I was younger was crucial for the development of my curiosity, critical thinking, and argumentation abilities.

Finally, there is only one person who knows all the struggle that I have been through to start, pursue, and finish my PhD. My partner Niccolò has constantly reminded me that I am a human being and as such I should accept that I can fail, but also encouraged me not to find excuses when I was tempted by it. The so many things I learned about myself through him made me the researcher, lecturer, supervisor I am and will be, and compensate for the cruel evidence that he still does not get what morphology exactly is (but after all, we don't know it, either).

In the past years, I have also become increasingly aware about the role that privilege played in my personal development. I had the privilege of being born in the EU. I had the privilege of being raised by parents with higher education. I had the privilege of attending a private university so that I could study exactly what I had in mind. I had the privilege of doing my PhD at a university with many resources and opportunities for discussion and training. I had the privilege of presenting my work at many conferences, always fully funded, even when these were expensive conferences at which many countries are dramatically under-represented. I also had the privilege of being supported by a lovely family and parter, and by a healthy body. My long term commitment for my academic life after my PhD is to do my best to make sure that people who are less privileged than me can have access to the same opportunities that I was offered.

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Summary

In recent years, a substantial number of psycholinguistic studies and of studies on acquired language impairments have investigated the case of morphologically complex words. These have provided evidence for what is known as 'morphological decomposition', i.e. a mechanism that decomposes complex words into their constituent morphemes during online processing. This is believed to be a fundamental, possibly universal mechanism of morphological processing, operating irrespective of a word's specific properties. However, current accounts of morphological decomposition are mostly based on evidence from suffixed words and compound words, while prefixed words have been comparably neglected. At the same time, it has been consistently observed that, across languages, prefixed words are less widespread than suffixed words. This cross-linguistic preference for suffixing morphology has been claimed to be grounded in language processing and language learning mechanisms. This would predict differences in how prefixed word are processed and therefore also affected in language impairments, challenging the predictions of the major accounts of morphological decomposition.

Against this background, the present thesis aims at reducing the gap between the accounts of morphological decomposition and the accounts of the suffixing preference, by providing a thorough empirical investigation of prefixed words. Prefixed words are examined in three different domains: (i) visual word processing in native speakers; (ii) visual word processing in non-native speakers; (iii) acquired morphological impairments. The thesis additionally contributes to the current evidence on prefixed words by investigating different types of linguistic phenomena, some of which were previously undocumented. The processing studies employ the masked priming paradigm, tapping

into early stages of visual word recognition. Instead, the studies on morphological impairments investigate the errors produced in reading aloud tasks.

As for native processing, the present work first focuses on *derivation* (Publication I), specifically investigating whether German prefixed derived words, both lexically restricted (*inaktiv* 'inactive') and unrestricted (*unsauber* 'unclean') can be efficiently decomposed. I then present a second study (Publication II) on a Bantu language, Setswana, which offers the unique opportunity of testing *inflectional* prefixes, and directly comparing priming with prefixed inflected primes (*dikgeleke* 'experts') to priming with prefixed derived primes (*bokgeleke* 'talent'). With regard to non-native processing (Publication I), the priming effects obtained from the lexically restricted and unrestricted prefixed derivations in native speakers are additionally compared to the priming effects obtained in a group of non-native speakers of German. Finally, in the two studies on acquired morphological impairments, the thesis investigates whether prefixed derived words yield different error patterns than suffixed derived words (Publication III and IV) and, additionally, if errors involving prefixes are genuinely morphological (Publication IV).

For native speakers, the results show evidence for morphological decomposition of both types of prefixed words, i.e. lexically unrestricted and restricted derivations, as well as of prefixed inflected words. Furthermore, non-native speakers are also found to efficiently decompose prefixed derived words, with parallel results to the group of native speakers. I therefore conclude that, for the early stages of visual word recognition, the relative position of stem and affix in prefixed versus suffixed words does not affect how efficiently complex words are decomposed, either in native or in non-native processing. While this result can be accounted for by the major accounts of morphological decomposition, these fail to capture previous findings on inflected words. I therefore provide un updated model of the early stages of visual word recognition, during which the processing system only differentiates between lexical units (stems or derivational affixes) and bundles of grammatical features (inflectional affixes), which is able to capture both the current results and the results from previous literature.

In the studies on acquired language impairments, instead, prefixes are consistently found to be more impaired than suffixes. This is explained in terms of a learnability disadvantage for prefixed words, which may cause weaker representations of the information encoded in affixes when these precede the stem (prefixes) as compared to when they follow it (suffixes). Based on the impairment profiles of the individual participants and on the nature of the task, this dissociation is assumed to emerge from later processing stages than those that are tapped into by masked priming. I therefore conclude that the different characteristics of prefixed and suffixed words *do* come into play at later processing stages, during which the lexical-semantic information contained in the different constituent morphemes is processed. This is also in line with previous psycholinguistic findings tapping into later, lexical stages of processing.

The findings presented in the four manuscripts, either published or under review, significantly contribute to our current understanding of the mechanisms involved in processing prefixed words. Crucially, the thesis constrains the processing disadvantage for prefixed words to later processing stages, thereby suggesting that theories trying to establish links between language universals and processing mechanisms should more carefully consider the different stages involved in language processing and what factors are relevant for each specific stage.

1. General Introduction

> «For the linguist, who is concerned with the fully developed structure of language, its acquisition and dissolution cannot fail to provide much that is instructive. These three aspects of language have not yet undergone a systematic comparative analysis»
>
> – (Jakobson, 1941–1968, p. 1)

Words are an essential ingredient of our language experience. Speakers of American English are estimated to know on average around 42,000 words, not including inflected forms or multi-word expressions (Brysbaert, Stevens, Mandera, & Keuleers, 2016). However, we are so used at understanding, using, and retrieving words that we hardly think about the specific mechanisms that make all this possible. At the same time, we have all experienced that some words are harder to be acquired than others, for example when learning a foreign language, or when observing the language development of young children. Similarly, those who experience attrition of their mother tongue because of lack of exposure, or language loss due to brain damage or dementia, or yet those who simply experience word retrieval difficulty due to aging, often notice that some words are retained more easily, while others are lost more quickly.

Yet, what is it exactly that makes some words more effortful to process or acquire? What precisely causes some types of words to be more affected than others in language loss? The present dissertation is devoted to these questions, with a specific focus on the case of morphologically complex words, i.e. those words that have an internal structure such as *player* [play][-er], *replay* [re-][play], or *playground* [play][ground].

In his pioneering work *Child Language, Aphasia and Phonological Universals* (original title *Kidersprache, Aphasie und allegmeine Lautgesetze*), Jakobson (1941–1968) suggested that language universals, child language acquisition, and language loss are closely inter-connected, so that language universals can precisely predict the order in which linguistic phenomena are learned in language acquisition and how these are affected in aphasia. Taking the specific case of phonological oppositions, the author showed that the oppositions that are observed more rarely in the world's languages are also acquired later in children's language development, and lost earlier in language loss.

In the present dissertation, I follow Jakobson's (1941–1968) approach to investigate the case of prefixed words, i.e. morphologically complex words in which a stem is preceded by an affix, such as in *replay*, which is composed by the prefix *re-* and the stem *play*.

Why prefixed words? Typological investigations of morphologically complex words have shown a cross-linguistic preference to forming words by means of suffixation rather than prefixation (e.g. Greenberg, 1963), which, in the light of the approach inspired by Jakobson (1941–1968) that I pursue in the present thesis, makes prefixed words a particularly relevant test case to investigate. Experimental research on morphologically complex words has gained ground since the publication of the study by Taft & Forster (1975), actually a study on prefixed words, which was possibly the first study specifically investigating whether complex words are decomposed during lexical processing. Since then, Taft's paper has collected over 1,200 citations in scientific publications, and morphological decomposition has become an established topic at major psycholinguistics and neurolinguistics conferences. The questions being asked to-date go well beyond the bare notion of morphological decomposition. However, experimental research on morphologically complex words has mostly focused on suffixed or compound words, and much less has been done on prefixed words. Research on prefixed words has been restricted to a limited range of languages, linguistic phenomena, and populations.

Jakobson's (1941–1968) work based on three pillars: (i) language universals, (ii) language acquisition, and (iii) language loss. Adopting a similar rationale, the present thesis takes as starting point the typological distribution of prefixed words across the world's languages (i), to investigate how this interacts with the way prefixed words are processed, in both native processing (ii) and in non-native processing (iii) – thus extending Jakobson's approach from the domain of language *acquisition* to the domain of *processing* – and with how prefixed words are impaired in language loss (iv).

Section 1.1 'Prefixed words and the suffixing preference' discusses the cross-linguistic preference for suffixing morphology and the major accounts that have been proposed to explain it. I then present the notion of morphological decomposition, some relevant current questions addressed in more recent literature, and the findings from research on prefixed words in section 1.2 'Morphological decomposition and prefixed words'. Finally, Section 1.3 'Aims and objectives' introduces the research questions underlying the present dissertation and briefly explains the structure of the experimental investigations I conducted to address them.

1.1. Prefixed words and the suffixing preference

The present thesis is specifically concerned with the types of complex words that are formed by joining an affix with a stem. These can be derived words (e.g. *player* [play][-er], *playful* [play][-ful], *replay*[re-][play]) or inflected words (*plays* [play][-s], *played* [play][-ed]). According to whether the affix is placed before or after the stem we distinguish between prefixation (*replay*) and suffixation (*player*). There is yet a third case of affixation, namely infixation, which is virtually absent in Indo-European languages (Sapir, 1921) and consists in placing the affix in the middle of a stem; because the present thesis does not deal with this phenomenon, this is not going to be further discussed.

As already described in the work by Sapir (1921), suffixing morphology (e.g. *player*, *playful*, *played*) is consistently more widespread than prefixing morphology (e.g. *replay*) across the world's languages. This universal preference for suffixation over prefixation was included in Greenberg's (1963) list of 45 language universals on the order of meaningful elements:

> «Universal 26. If a language has discontinuous affixes, it always has either prefixing or suffixing or both. As between prefixing and suffixing, there is a general predominance of suffixing. Exclusively suffixing languages are fairly common, while exclusively prefixing languages are quite rare»
>
> – (Greenberg, 1963, p. 73).

A cross-linguistic preference for suffixation has been additionally observed in a series of surveys comprising larger and more diverse language samples than Greenberg's (1963) survey, which only included 30 languages. Hawkins and Gilligan (1988) considered a corpus of data from around 200 languages drawn from three samples and found suffixation to be prevalent both in terms of number of languages that are exclusively prefixing versus exclusively suffixing, and in terms of relative occurrence of prefixes and suffixes within and across languages. Their analysis focused primarily on inflectional morphology. Similarly, in The World Atlas of Language Structures Online (WALS

Online; Dryer, 2013), which includes 969 languages, about half of the languages were found to predominantly use suffixing inflectional morphology, outnumbering the languages that are predominantly prefixing at a ratio of about seven to one. As for derivational morphology, in their survey of 55 languages, Štekauer, Valera, and Kőrtvélyessy (2012) found 53 languages that make use of derivational suffixes and 39 that present with derivational prefixes. While many languages have both prefixes and suffixes, within the same language suffixes are generally more common than prefixes: St. Clair, Monaghan, and Ramscar (2009) report that there are 181 suffixes and 56 prefixes in Fudge's (1984) comprehensive list of English affixes, both derivational and inflectional.

Two prominent accounts have been proposed for why suffixing is so dominant across the world's languages as compared to prefixing morphology: the *processing account* by Cutler, Hawkins, and Gilligan (1985) and the *learnability account* by St. Clair et al. (2009).

The processing account

The account by Cutler et al. (1985; see also Hawkins & Cutler, 1988; Hawkins & Gilligan, 1988) is by far the most prominent psycholinguistic account of the suffixing preference. The starting point of their work was an investigation of whether a language's word order can predict its use of prefixing versus suffixing morphology. By analyzing the language sample of Hawkins and Gilligan's (1988) language survey, the authors found that word order only provides a partial account of the use of prefixation versus suffixation. Languages in which direct objects precede verbs (OV languages; e.g. *the book bought*) and/or noun phrases precede postpositions (NP + Po languages; e.g. *the table on*) tend to exclusively make use of suffixing morphology. Instead, languages in which verbs precede direct objects (VO languages; e.g. *bought the book*) and/or prepositions precede noun phrases (Pr + NP languages; e.g. *on the table*) present prefixes and/or suffixes. In other words, while exclusively prefixing languages are always VO and/or Pr + NP languages, exclusively suffixing languages are of both word order types. The authors thus conclude that, while there is a general principle predicting a correlation between word order and affixation type, there must be another major principle that is opposed to the former and that accounts for the prevalence of suffixing morphology. Cutler et al. (1985) thus suggest that this counter-principle has to do with language processing mechanisms, basing their claim on two major psycholinguistic findings. The first finding is that word onsets are more salient than word endings for lexical processing: for example, distorting the initial portions of words causes more disruptive effects than distorting word-medial or word-final portions, and word beginnings are more successfully used as cues for word recall or word recognition (e.g. Cole, 1973; Nooteboom, 1981). The second relevant finding is that, during the processing of morphologically complex words, stems and affixes are processed in different ways (e.g. Lima & Pollatsek, 1983), which implies that our processing mechanisms differentiate the processing of the lexical/semantic information carried by the stem from the grammatical/semantic information encoded by affixes. Taking these two findings together, the authors suggest that the portion of the word which is more relevant for lexical recognition, i.e. the stem, should preferably occur in the portion of the word that is more salient for processing, i.e. word-initially.

As noted by Hall (1988, see also 1992), the processing account is also in line with diachronic considerations about the origin of affixes. Affixes have been claimed to originate from free-standing grammatical material (Givón, 1979): for example, verbal affixes would originate from auxiliaries or modals. The question would then be why such grammatical items are more likely to fuse with a preceding word (thus forming a suffixed word) than with a subsequent word (thus forming a prefixed word), which can be easily explained in terms of the language processing constraints postulated by Cutler et al. (1985).

More recently, Hupp, Sloutsky, and Culicover (2009) additionally showed that a 'suffixing preference' also applies to the processing of different types of non-linguistic temporal sequences (e.g. sequences of music notes or objects), so that adding an element to the end of a sequence is perceived as a smaller modification than adding an element to its beginning. They thus argued that the suffixing preference is not specific to language processing, but rather has to do with domain-general processing mechanisms that underly sequential processing.

The learnability account

St. Clair et al. (2009; see also Ramscar, 2013) looked at the suffixing preference from the perspective of the 'learnability' of linguistic phenomena, the idea being that certain linguistic phenomena are cross-linguistically more widespread because they are more easily learnable than others. Why would then suffixing morphology be learned more easily than prefixing morphology? The authors suggest that that is because suffixing morphology promotes the learning of the grammatical properties of a word (expressed by the affix) more than prefixing morphology. This idea was originally formulated by Greenberg (1957) and is rooted in Osgood's (1949) theories on associative human learning, and specifically on the idea that the relationship between stimulus and response is easier to learn in so-called 'convergent' than 'divergent' hierarchies. Convergent hierarchies indicate a situation in which the stimuli are varied but they are associated with the same response, while divergent hierarchies describe a situation in which the stimuli are similar but the responses associated to them are varied. According to Greenberg (1957), Ramscar (2013), and St. Clair et al. (2009), convergent hierarchies would be analogous to suffixing morphology: in suffixed words, a large set of alternatives (stems) are followed by a smaller, less varied class of alternatives (affixes). Divergent hierarchies would instead be similar to prefixing morphology, because a small class of alternatives (affixes) are followed by a larger, more varied class (stems). From these considerations, the authors derive the prediction that the properties of the stem that are encoded by the affix should be easier to learn in the case of suffixation than prefixation. To test their prediction, they designed a series of tasks in which participants were asked to learn an artificial language. In St. Clair et al. (2009), participants were tested on their ability to learn the word category expressed by two suffixes and two prefixes; results showed higher accuracy in the suffix than in the prefix condition. Furthermore, Ramscar (2013) showed that nouns learned with consistent suffixes were judged to be more similar to each other than nouns learned with consistent prefixes, which suggests that suffixing promotes the learning of the similarities between items sharing the same affix more than prefixing does.

Child language acquisition

Studies on child language acquisition have consistently shown a preference for suffixing morphology in language learning, which confirms the predictions of the learnability account. Overall, children acquire prefixes later than suffixes (Clark, 2001). Furthermore, speakers of prefixing languages, such as Mohawk (mostly spoken in Quebec and Ontario, Canada, and in New York State, USA) have been shown to acquire inflection later in life than speakers of suffixing languages (Mithun, 1989) – although we probably do not have enough data from prefixing languages to draw strong conclusions. In some experiments with pre-school children involving learning of novel prefixes and suffixes, Kuczaj (1979) found that sentences containing novel suffixes were imitated more accurately than sentences containing novel prefixes, and that, in an elicitation task, suffixes were used more accurately than prefixes. Finally, in a study investigating how morphological structure aids visual word recognition in children (grade 2 to 6), Hasenäcker, Schröter, and Schroeder (2017) found that effects of morphological decomposition emerge earlier in life for suffixed words than for prefixed words. The finding of easier acquisition for suffixing than prefixing morphology can be summarized by the following language acquisition universal by Slobin (1973), derived from a language acquisition dataset of over 40 languages: «For any given semantic notion, grammatical realizations in the form of suffixes or postpositions will be acquired earlier than realizations in the form of prefixes or postpositions» (p. 192).

Predictions for language processing and language loss

The processing and the learnability accounts provide two different perspectives on the suffixing preference, starting from different assumptions – respectively, serial processing and theories of human learning –. Their claims are based, in both cases, on the hypothesis that the relative position of stem and affix should make a difference in how affixed words are, respectively, processed and learned. However, the main focus of the processing account is on processing the information encoded by the *stem* of complex words. Instead, the learnability account rather focuses on learning the properties encoded by *affixes*. The processing account, in particular, has major implications for the purposes of the present dissertation, since, according to this account, we should be able to observe a processing disadvantage for prefixed words, possibly both in native and non-native language processing; furthermore, a processing disadvantage for prefixed words may also affect how easily these are retrieved in acquired language impairments and therefore how heavily they are impaired. The implications of the learnability account mostly pertain the level of language acquisition, for which the literature already presents with convincing evidence for a suffixing preference. However, a learnability disadvantage for prefixed words may also affect second language processing, if prefixing morphology has not been properly acquired. Furthermore, the use of prefixing morphology to specify the properties of stems may not only be acquired later, but also lost earlier.

Therefore, we can derive some general predictions about how prefixed words are processed and impaired, as compared to suffixed words. First, prefixed words should present with larger processing costs than suffixed words. Processing prefixed words may be particularly challenging for non-native speakers, for whom the learnability disadvantage of prefixed words may add to the larger processing demands. Finally, prefixed words should also be more affected in aphasia than suffixed words. This raises the question of how we should measure such disadvantage for prefixed words in language processing and language loss. In order to be able to formulate precise predictions, which can be accepted or refuted on the basis of experimental evidence, it is useful to start from the current methods and questions in the field of morphological processing and in the investigations of morphology in aphasia, which have mostly focused on suffixed words, and apply them to the investigation of prefixed words. In the following section, '1.2 Morphological decomposition and prefixed words', I will present the notion of 'morphological decomposition' and explain the key methods that have been employed to investigate morphology in language processing and language loss. I will then discuss some relevant findings about morphological decomposition and its constraints, mostly investigated for suffixed words or compound words, and finally review the current findings on prefixed words, which have been much less investigated.

1.2 MORPHOLOGICAL DECOMPOSITION AND PREFIXED WORDS

How morphologically complex words are processed and represented in the mental lexicon has been the subject of a growing number of experimental studies since the mid-1970s, both in psycholinguistic research and in research on aphasia (see, for example, the early experimental studies by Job & Sartori, 1984; Manelis & Tharp, 1977; Patterson, 1980; Taft & Forster, 1975). A key notion in the field of morphological processing is that of ***morphological decomposition***, which was first introduced by Taft and Forster (1975) and refers to the finding that, during processing, morphologically complex words are segmented into their basic constituents, or 'morphemes'. For example, *player* is decomposed into the stem *play* and the affix *-er*, or *playground* into the two stems *play* and *ground*. Morphological decomposition has been assumed to be a universal mechanism of morphological processing, which operates for all types of morphological forms and in any language. Indeed, a series of psycholinguistic studies on adult native speakers have reported evidence for morphological decomposition of derived words (e.g. J. Li et al., 2017a; Rastle, Davis, Marslen-Wilson, & Tyler, 2000), inflected forms (e.g. Kirkici & Clahsen, 2013; Meunier & Marslen-Wilson, 2004), compound words (e.g. Beyersmann et al., 2018; Duñabeitia, Laka, Perea, & Carreiras, 2009; Fiorentino & Fund-Reznicek, 2009), as well as in the case of non-concatenative, or discontinuous, morphological forms (i.e. in Semitic languages; e.g. Boudelaa & Marslen-Wilson, 2005). Furthermore, although a large body of evidence comes from English (e.g. Fiorentino & Fund-Reznicek, 2009; Rastle et al., 2000; Silva & Clahsen, 2008), effects of morphological decomposition have been shown in a series of other typologically different languages, such as Spanish (e.g. Domínguez, Cuetos, & Segui, 2000), Russian (e.g. Kazanina, Dukova-Zheleva, Geber, Kharlamov, & Tonciulescu, 2008), Basque (e.g. Duñabeitia et al., 2009), Japanese (e.g. Clahsen & Ikemoto, 2012; Fiorentino, Naito-Billen, & Minai, 2016), Korean (e.g. Kim, Wang, & Taft, 2015), and Turkish (e.g. Kirkici & Clahsen, 2013). Research on language loss has provided additional evidence for a level of morphological decomposition by investigating the errors produced by individuals with acquired language impairments, again by looking at different language families and phenomena, such as derivation and inflection in Hebrew (Reznick & Friedmann, 2015), prepositional prefixes in Slovenian (Semenza, Girelli, Spacal, Kobal, & Mesec, 2002), and compound words in German (Lorenz, Heide, & Burchert, 2014) and Italian (Marelli, Aggujaro, Molteni, & Luzzatti, 2012).

Measures and methods

Morphological decomposition can be investigated using a number of different techniques, which provide insight into different stages of processing or different processing modalities. In the present section, I will specifically focus on the measures and paradigms that were employed in the empirical investigations of my dissertation. These are reaction times (RTs) from lexical decision tasks with the masked priming paradigm and error data from reading aloud tasks.

In psycholinguistic research, a very widespread measure employed to investigate word recognition are response latencies from lexical decision tasks (e.g. Taft & Forster, 1975; see Amenta & Crepaldi, 2012 for a review), in which participants are asked to decide if a series of words presented on a computer screen are existing words of a given language. Several studies in this domain have manipulated specific properties (such as frequency) of the stems of complex words with the assumption that, if complex words are decomposed into their components during processing, then the time it takes to recognize a complex word would also be influenced by the properties of its stem. For example, complex words with frequent stems should be faster to recognize than complex words with less frequent stems (e.g. Taft, 2004). However, as pointed out by Marslen-Wilson (2007), since this manipulation compares different words in each condition (e.g. words with high-frequency stems vs. words with low-frequency stems), it is generally difficult to safely rule out other factors that could explain the reported effects. This is possibly one of the reasons why the priming technique, especially *masked priming* (Baayen, 2014; Forster, 1998) has gained ground in reaction-times experiments on visual word-recognition. In a priming experiment, participants are asked to perform a lexical decision on a series of target words that are preceded by so-called prime words. When primes and targets are morphologically related, e.g. the prime is a derived form of the target (such as in *player-play*), lexical decisions to target words are faster than when targets are preceded by primes unrelated in morphology, form, or meaning (e.g. *worker-play*). This effect is attributed to morphological decomposition of the prime into its constituents (e.g. [play][-er]), causing pre-activation of the target word before it is actually presented, which would in turn facilitate its subsequent recognition (e.g. Rastle, Davis, & New, 2004). An advantage of the priming technique is that lexical decisions are generally performed on the stems rather than on the complex words themselves, which allows investigating priming effects on the same stems with different types of morphologically related primes, e.g. both inflected (*played-play*) and derived (*player-play*), thus at least attenuating the confound that may arise by testing different lists of items. In *masked* priming, both prime and target are presented visually on a computer screen, but the prime word is presented for only very brief durations (generally between 30 and 70 ms) and is preceded by a visual mask (such as a series of hashes). This way, participants cannot consciously perceive the presence of the prime, which also prevents the occurrence of strategic effects. Because masked priming effects are reliable even when primes are non-existing words (e.g. Beyersmann, Cavalli, Casalis, & Colé, 2016; Kim et al., 2015; Longtin & Meunier, 2005), this technique is believed to tap into the very early stages of visual word recognition that precede lexical access. Instead, when both primes and targets are fully visible or audible, so-called 'overt priming', effects are believed to reflect a level of central lexical representation of complex words, i.e. how complex words are represented in the mental lexicon (Marslen-Wilson, 2007).

As for studies on morphology in acquired language disorders, the most common type of data being analyzed are error counts and types of errors produced by language-impaired individuals. These studies typically present case studies or case series, the underlying assumption being that the language processing mechanisms and the organization of the language system are constant across all speakers, so that even the impairment of a single individual is informative about how the language system works for all speakers, and therefore needs to be accounted for by theoretical accounts of language processing mechanisms (Coltheart, 2001). An advantage of this approach is that we can obtain data (numbers and types of errors) from rather naturalistic tasks, without the need of elaborated, somehow artificial, experimental designs.

Research on morphological decomposition in language loss specifically involves individuals with impaired use of morphology, which is a defining symptom of agrammatic aphasia and, when it comes to reading, of deep and phonological dyslexia (Coltheart, 1980; Luzzatti, Mondini, & Semenza, 2001; Rastle et al., 2006; Semenza & Mondini, 2015). However, cases of morphological impairments have also been reported in fluent aphasias ('jargon aphasia': Caplan, Kellar, & Locke, 1972; Semenza, Butterworth, Panzeri, & Ferreri, 1990), as well as in other neuropsychological disorders, such as semantic dementia (Auclair-Ouellet et al., 2016a, 2016b; Auclair-Ouellet, Fossard, Laforce, Bier, & Macoir, 2017) or neglect (Marelli, Aggujaro, Molteni, & Luzzatti, 2013; Reznick & Friedmann, 2015; Semenza, Arcara, et al., 2011). Individuals with morphological impairments make more errors in reading or producing morphologically complex words than with otherwise matched simple words, and they produce so-called 'morphological errors', i.e. errors that reflect the complex morphological structure of the target words (Rastle et al., 2006; Semenza & Mondini, 2015). In inflected and derived words, morphological errors typically involve affixes, which are omitted or substituted (e.g. *playful* → «play» or «player»), at least in agrammatic aphasia and acquired dyslexia, while a few cases in which stems are impaired and affixes are spared have been reported for fluent aphasias (Semenza et al., 1990); in compounds, morphological errors involve one of the stems while sparing the other (e.g. *playground* → «play» or «background»).

The patterns of errors observable in acquired language impairments are believed to be informative with respect to how the language system is organized (Caplan, 1993). In the case of errors produced in reading words aloud, the case of individuals who are unable to read non-existing words (such as speakers with deep and phonological dyslexia; Luzzatti et al., 2001) can be particularly informative, since these are assumed to read through the so-called 'lexical route'. This assumption is based on dual-route models of reading aloud (e.g. Coltheart et al., 2001; Luzzatti, 2008). Such models postulate that one route available for reading aloud is grapheme-to-phoneme mappings, i.e. a bare conversion of letter strings into the corresponding phonemes. This route can be used to read words with regular orthography, but not for words with irregular orthography such as *pint*, and is the only route available to read non-existing words. In the lexical route, instead, the input letter string is directly matched to an entry in mental lexicon; for the case of reading aloud, these models normally distinguish between entries in the 'input orthographic lexicon', activated by the visual input, and the corresponding entries in 'phonological output lexicon', needed for producing the word. Studies on impairment of morphology also point at a modality independent, central level of representation of entries in the mental lexicon (e.g. Marelli et al., 2013; Luzzatti et al., 2001; Rastle et al., 2006), consistently with psycholinguistic evidence (Marslen-Wilson, Bozic, & Randall, 2008). The results from the analysis of errors in language loss does not allow being as accurate as the masked priming technique with regard to the specific stage of word processing that we tap into; however, some insights about the stage at which morphological errors arise can be obtained by trying to identify the locus of the disorder of the participants involved, generally with thorough preliminary assessments (see e.g. Badecker, Hillis, & Caramazza, 1990).

Constraints on morphological decomposition

Three major accounts have been proposed to explain how morphological decomposition operates. According to the *affix stripping* account, affixes are stripped off from stems any time we encounter words that are decomposable. This mechanism operates already in the very early, pre-lexical stages of visual word recognition, so that even words that are not truly morphologically complex would be decomposed, such as the pseudo-complex word *corner*, which superficially looks as if it was composed of the stem *corn* and the affix *-er* (Rastle et al., 2004; Taft & Forster, 1975). Instead, the *edge-aligned embedded word activation* account postulates that morphological decomposition originates from extraction of embedded words (or stems) at both edges of letter strings, even if these are not morphologically complex or pseudo-complex words, e.g. in the case of *scandal*, which contains the stem *scan* plus a non-morphological letter string (Grainger & Beyersmann, 2017). Both these accounts think of morphological decomposition as a mechanism relying on the surface form of complex words. The third major account of morphological decomposition, the *single-route full decomposition* account, instead, considers morphology on a more abstract level, suggesting that complex words are decomposed into their abstract morphemes based on grammatical rules, even when there are no overt affixes, such as in *sang*, which would be decomposed into the stem *sing* and an abstract morpheme expressing past tense (Stockall & Marantz, 2006).

What all these accounts have in common is that they all postulate a general mechanism of morphological decomposition, which is assumed to operate in the same manner for all types of complex words, irrespective of their specific characteristics or of other factors that may constrain its efficacy. However, a line of research on morphological processing has moved forward from the basic question of morphological decomposition *per se*, to investigate the constraints on such basic processing mechanism. In other words, the question being asked is whether this mechanism operates in the very same way with all types of complex words, or whether it is also sensitive to the specific linguistic properties of words.

Indeed, there is evidence that morphological decomposition is at least partly based on different mechanisms for inflected and derived words, as suggested by some psycholinguistic experiments tapping into lexical representations of complex words (e.g. Clahsen, Sonnenstuhl, & Blevins, 2003; Feldman, 1994; Stanners, Neiser, Hernon, & Hall, 1979), as well as by studies investigating how these words are impaired in aphasia (e.g. Tyler & Cobb, 1987; Miceli & Caramazza, 1988). For the early, pre-lexical stages of visual word recognition that masked priming taps into, the distinction between derived and inflected words does not play a role for native processing, but evidence for less efficient morphological decomposition of inflected words compared to derived words has been reported in a series of studies on non-native ('L2') speakers (e.g. Jacob, Heyer, & Veríssimo, 2018; Kirkici & Clahsen, 2013; Silva & Clahsen, 2008). Another linguistic factor that has been found to modulate morphological decomposition is whether morphological processes only apply to restricted sets of lexical items, as compared to morphological processes that are lexically unrestricted. This is the case of irregular and regular inflection, which are respectively cases of lexically restricted (i.e. they only apply to a pre-defined set of words) and unrestricted phenomena. Different effects for irregularly and regularly inflected words have been reported in masked priming, with more efficient priming for regularly inflected words (e.g. Morris & Stockall, 2012; Pastizzo & Feldman, 2002; Rastle, Lavric, Elchlepp, & Crepaldi, 2015), even when irregular forms are fully parsable into stems and affixes (Neubauer & Clahsen, 2009). Similar effects have been reported for overt priming (Sonnenstuhl, Eisenbeiss, &

Clahsen, 1999). Finally, this distinction also applies to the errors produced by individuals with aphasia, for which dissociations in the impairment of regular and irregular inflection have been reported (e.g. Hamilton & Coslett, 2008; Ullman et al., 2005). In derived words, lexical restrictions do not seem to affect morphological decomposition (see e.g. the masked priming study on the English derivational suffixes *-ness* and *-ity* by Silva & Clahsen, 2008), but this has been much less investigated than the distinction between regular and irregular inflection.

The processing of complex words has also been shown to be sensitive to the properties of the units resulting from morphological decomposition. For example, while stems are always extracted efficiently from a complex word, even when they do not occur in the right position (e.g. **moonhoney*), the recognition of affixes is position-specific (Crepaldi et al., 2016; Crepaldi, Rastle, Davis, & Lupker, 2013), which suggests different mechanisms underlying the processing of these two types of morphemes. Furthermore, in acquired morphological impairments, affixes are generally more impaired than stems, but the opposite dissociation, with preserved stems and impaired affixes has also been reported (Semenza et al., 1990; Tyler, Behrens, Cobb, & Marslen-Wilson, 1990). The mechanisms underlying morphological processing also distinguish between head and non-head morphemes, an effect that, in the compound literature, is known as 'headedness effect'. For example, larger priming effects have been reported for head constituents than for non-heads (Marelli, Crepaldi, & Luzzatti, 2009), though only under overt priming conditions, but not under masked priming conditions (Fiorentino & Fund-Reznicek, 2009; see also the study on L2 by M. Li et al., 2017b). Furthermore, head constituents are retained better in language loss than non-head constituents (e.g. Marelli et al., 2013; Semenza, De Pellegrin, et al., 2011).

Another relevant question on morphological decomposition is under what circumstances effects that may seem to be purely morphological in nature originate in fact from other sources, which would indeed constrain the universality of this mechanism. Words such as *player*, *playful*, *played*, and *play* are not only morphologically related, in that they all share the stem *play*, but they also overlap orthographically and semantically, i.e. they also share a sequence of letters and have related meanings. This poses the question to what extent effects that have been claimed to reflect morphological decomposition can in fact be explained in terms of orthographic or semantic effects. Isolating effects that are purely morphological is not trivial. This is indeed one the reasons why masked priming is so popular: under masked priming conditions, bare semantic (*game-play*) or orthographic (*pray-play*) relatedness between prime and target do not speed up word recognition, which implies that effects of morphological relatedness (*player-play*) should be truly morphological (e.g. Rastle et al., 2000; note that this may work differently for non-alphabetic scripts: see Nakano, Ikemoto, Jacob, & Clahsen, 2016). However, recent research on L2 speakers has challenged this view. A series of masked priming experiments on L2 speakers reported significant effects not only for morphologically related, but also for orthographically related prime-target pairs (Diependaele, Duñabeitia, Morris, & Keuleers, 2011; Feldman, Kostić, Basnight-Brown, Đurđević, & Pastizzo, 2010; Heyer & Clahsen, 2015; J. Li & Taft, 2019; J. Li et al., 2017a; M. Li et al., 2017b). As suggested by Heyer and Clahsen (2015), this may imply that morphological masked priming effects in L2 are in fact only orthographic, which would pose a constraint on the universality of morphological decomposition.

The question about whether morphological effects are dissociable from effects of form and meaning has also been a major topic in the domain of language loss, specifically with regard to the morphological errors produced in reading aloud. Indeed, individuals who produce morphological errors in reading aloud often also produce semantic errors (words that are semantically related, but orthographically unrelated to the target, e.g.

wood → «forest») and visual errors (words that are orthographically related, but semantically unrelated to the target, e.g. *wood* → «mood»). This is especially the case in deep dyslexia, while individuals with phonological dyslexia produce visual errors, but not semantic errors (Coltheart, 1980; Funnell, 2000). For this reason, morphological errors in reading aloud have been claimed to be bare instances of visual and/or semantic errors (Funnell, 1987). Convincing evidence that morphological errors are distinguishable at least from visual errors was provided by Rastle et al. (2006). The authors report a case of deep dyslexia who produced significantly more morphological errors with truly morphologically complex items (*player* [play][-er]) than with pseudo-complex words (*corner* [corn][-er]) and words with embedded stems (*cashew* [cash]), which suggests that morphological errors can be dissociated from visual errors. The fact that these results were replicated even with individuals with phonological dyslexia, who do not make semantic errors (e.g. Hamilton & Coslett, 2008), additionally suggests that these errors cannot be semantic in nature.

Experimental research on prefixed words

Experimental research about morphological decomposition all started from the study about prefixed words by Taft and Forster (1975). In a series of visual lexical decision tasks, the authors found that non-words are harder to reject (both in terms of accuracy of responses and RTs) when they are bound stems of existing prefixed words, such as *juvenate* (which occurs in *rejuvenate*) as compared to non-words that do not occur as stems of prefixed words, such as *luvenate*. They additionally found that prefixed non-words are harder to reject when they contain bound stems, e.g. *dejuvenate*, than when they do not contain possible stems, e.g. *depertoire*. These results were taken to reflect a mechanism of morphological decomposition which operates in the very early, pre-lexical stages of visual word processing (see also Taft, 1981). Taft (1979) additionally showed that lexical decision RTs to prefixed words are modulated by their stem frequency, which, again, supports the idea that the processing of prefixed words involves morphological decomposition into stems and affixes. Since then, subsequent experimental research on morphological decomposition, both in word recognition experiments with language unimpaired adults and in investigations of morphological errors in aphasia, has built research questions and predictions based on Taft's account.

A series of masked priming studies have reported significant priming effects with prefixed words, suggesting efficient morphological decomposition of prefixed words in the early stages of visual word processing. Experiments included different types of prime-target combinations: (i) prefixed words priming their stems, both with prefixed existing words (e.g. Diependaele, Sandra, & Grainger, 2009 on Dutch; Kazanina, 2011 on Russian; Kgolo & Eisenbeiss, 2015 on Setswana; Kim et al., 2015 on Korean; Mousikou & Schroeder, 2019 on German) and with prefixed pseudo-words (e.g. Beyersmann et al., 2016 on French; Heathcote, Nation, Castles, & Beyersmann, 2018 on English; Mousikou & Schroeder, 2019 on German); (ii) stems priming their corresponding prefixed targets (e.g. Forster & Azuma, 2000 on English; Grainger, Colé, & Segui, 1991 on French; Heide, Lorenz, Meinunger, & Burchert, 2010 on German; Nikolova & Jarema, 2002 on Bulgarian); (iii) finally, prefixed words priming prefixed targets sharing the same stem, both bound and free (e.g. Forster & Azuma, 2000 on English; Grainger et al., 1991 on French), or sharing the same prefix (e.g. Chateau, Knudsen, & Jared, 2002 on English; Domínguez, Alija, Rodriguez-Ferreiro, & Cuetos, 2010 on Spanish; Giraudo & Grainger, 2003 on French). Masked priming effects from prefixed existing words have been generally shown to be distinguishable from effects of pure formal overlap in prime-target pairs overlapping word-finally such as *suspend-spend* (e.g. Diependaele et al., 2009). However, the only masked priming study investigating the processing of prefixed words in an L2 group found similar magnitude of morphological and orthographic priming (J. Li & Taft, 2019).

Some of the above-mentioned masked priming studies exclusively tested prefixed words. Others, instead, additionally included suffixed items (Beyersmann et al., 2016; Giraudo & Grainger, 2003; Grainger et al., 1991; Kim et al., 2015; Mousikou & Schroeder, 2019). Of these, the study on French by Giraudo and Grainger (2003) found that, while priming from shared prefixes (e.g. *enjeu-envol* 'stake-takeoff') is distinguishable from priming from pseudo-prefixes, priming from suffixes is not distinguishable from priming from pseudo-suffixes. The authors explain this asymmetry between prefixation and suffixation in terms of serial left-to-right processing combined with lexically-driven parsing: lexical representations are formed based on left-to-right parsing, thus allowing prefixes, but not suffixes, to form lexical representations on their own. They additionally pointed out that, at least in French, prefixes have a stronger semantic function than suffixes, adding a meaning component to their stem in a similar way to compound modifiers. Furthermore, the study by Kim et al. (2015) reported priming with both prefixed and suffixed primes when these were existing words, but only with suffixed primes when these were pseudo-words. The authors took this finding to suggest that morphological decomposition of prefixed words is not pre-lexical and occurs at later stages. This would be in line with the processing account by Cutler et al. (1985), postulating more costly processing for prefixed than suffixed words, resulting from delayed access to the stem and therefore delayed morphological decomposition, as compared to suffixed words.

A series of other visual word recognition studies on prefixed and suffixed words, employing different techniques from masked priming, have also reported differences between prefixed and suffixed words. For example, in lexical decision tasks, Ferrari Bridgers and Kacinik (2017) report longer RTs to prefixed words than suffixed words, which may suggest larger processing costs for prefixed words. Bergman, Hudson, and Eling (1988) report equal RTs to suffixed and pseudo-suffixed words, suggestive of blind, automatic access to the stem, but longer RTs for pseudo-prefixed than prefixed words, for which stem access may therefore not be as automatic. Beauvillain (1996), in an eye-tracking study, found a cumulative root frequency effect on first fixations durations in the case of suffixed words, but only on second fixation durations in prefixed words, indicative of delayed access to the stem (for similar results, though only on prefixed words, see Niswander-Klement & Pollatsek, 2006). Similarly, Colé, Beauvillain, and Segui (1989), in a lexical decision task, found a cumulative root frequency effect on RTs to suffixed, but not to prefixed words. In a letter detection task, Beyersmann et al. (2015b) found that letter search takes longer when the letter is contained in suffixes compared to non-morphological endings, while no such difference was found for prefixes compared to non-morphological word beginnings. All these results support the idea that stem access may be less efficient in prefixed words compared to suffixed words, possibly because of the word-final position, and that therefore decomposition of prefixed words is at least less automatic, and therefore delayed – possibly even occurring only after lexical access.

Additional evidence for the hypothesis that morphological decomposition of prefixed words may only occur post-lexically was reported in the cross-modal priming experiment (with primes being presented aurally and targets visually) on French by Meunier and Segui (2002). The authors found that suffixed words prime their stems when there is a transparent phonological relationship between primes and targets, but not when primes and targets differ phonologically (such as in *surdité* 'deafness' and *sourd* 'deaf'), and took this result to reflect the inhibition processes between different phonological forms occurring in the early phases of lexical processing. Instead, prefixed words were found to prime their stems even when their relationship is phonologically non-transparent, which the authors took to suggest that morphological decomposition of prefixed words may occur at later stages of processing, in which such inhibitory processes do not take place, allowing priming effect to be observable for primes and targets whose forms differ phonologically.

In the auditory domain, several studies did not find any evidence for morphological decomposition of prefixed words. For example, Tyler, Marslen-Wilson, Rentoul, and Hanney (1988) showed that the recognition point of English prefixed words, as measured in gating, lexical decision, and naming tasks, is not predicted by the uniqueness point of their stem (i.e. the point in which the stem is unambiguously distinguishable from any other word), as a decompositional account would predict, but rather by the uniqueness point of their full form. Similar results were found by Schriefers, Zwitserlood, and Roelofs (1991) in gating and phoneme monitoring tasks in Dutch, as well as by Meunier and Segui (2003) in two lexical decision tasks in French (but see Wurm, 1997 for a different interpretation). Note that, in auditory word comprehension, the recognition of words necessarily follows some sequential processing of the sounds. According to the 'cohort' model of auditory word recognition by Marslen-Wilson and Tyler (1980), for example, words are recognized starting from a cohort of all possible words beginning with the same sounds; this cohort is gradually reduced while the word is being heard, so that, eventually, only one single element of the cohort remains active. This is indeed the model that Cutler et al. (1985) had in mind when they proposed their processing account of the suffixing preference, which is based on the assumption that the morphemes composing a complex word are processed in their serial order. However, whether serial processing also applies to visual word recognition and graphemes is more controversial. With regard to studies specifically investigating left-to-right processing in visual morphological processing, while some of them claimed that the serial presentation of morphemes plays a crucial role (e.g. Järvikivi & Niemi, 1999;

Libben, 1994), the account of morphological processing proposed by Grainger and Beyersmann (2017), i.e. the 'edge aligned embedded word activation', posits that stems (and embedded words in general) are activated at both edges of a letter string, which predicts that there should be no processing disadvantages for those cases in which the stem is word-final (prefixed words) as compared to when it is word-initial (suffixed words). The other two major accounts of morphological processing, 'affix stripping' and 'single-route full decomposition' also predict, more or less explicitly, that the position of the stem should make no difference for visual word recognition.

All in all, the picture resulting from the literature on morphological decomposition of prefixed words in visual word recognition is relatively mixed, and it is still unclear whether the word-final position of the stem in prefixed words represents another constraint on the efficacy of morphological decomposition. When it comes to studies investigating effects of morphological decomposition in reading aloud prefixed words in morphological impairments, the picture becomes even less clear. First, because most studies on morphological impairments focused on inflectional affixes, but prefixation, at least in the most commonly researched Indo-European languages, is exclusively found in derivational processes. Second, because even those studies testing derivation mostly focused on suffixed derivations, while prefixed derivations have hardly been directly investigated. Finally, because the literature completely lacks direct investigations of whether prefixed words are impaired differently from suffixed words.

The only study specifically investigating morphological errors in prefixed words is the one by Semenza et al. (2002). The authors analyzed the errors produced by two Slovenian individuals with non-fluent aphasia in reading aloud, repeating, and writing to dictation prefixed derived words, exploiting the large inventory of Slovenian derivational prefixes. Both participants were found to produce morphological errors with prefixed words. Overall, both of them produced a large number of errors in which the prefix was preserved and the stem was impaired. This differs from what has been usually reported for suffixed words, in which it is the affixes that are mostly affected (e.g. Kay, 1988; Miceli & Caramazza, 1988; Rastle et al., 2006). However, the prefixes tested in this study were all existing Slovenian prepositions, hence they were not bound morphemes, which makes it difficult to compare Semenza et al.'s (2002) findings to previous literature.

Other studies on acquired morphological impairments included sets of prefixed words among other sets of items, mostly testing suffixed words. For example, De Bleser and Bayer's (1990) investigation of a German individual with deep dyslexia includes a description of errors produced with words beginning with negation prefix *un-*. This was, in half of the cases, replaced by the free morpheme *nicht* 'not', even when it was part of non-transparent derivations (e.g. *unbillig* 'unfair' → «nicht billig» 'not cheap'). This is described as part of a general tendency to rephrasing affixes with a stronger semantic content, both prefixes and suffixes, as opposed to affixes that change the grammatical class of words without contributing much to their meaning, which were mostly omitted (e.g. *staubig* 'dusty' → «Staub» 'dust'). Hence, the conclusion the authors draw was not so much about prefixes and suffixes, but rather on the role of the semantic content of affixes overall. Another study including prefixed words is the one by Reznick and Friedmann (2015). They found that, in several individuals with neglect dyslexia, the chance of producing neglect errors increased with increasing word length, but not when the word's length was increased by adding a prefix, which they took as indicative of morphological decomposition. Impaired use of prefixed words has additionally been reported for other domains, such as in the study by Badecker et al. (1990) on an individual with acquired dysgraphia, who produced fewer errors in spelling prefixes than the corresponding beginning syllable of pseudo-prefixed words.

A relevant line of research concerns whether errors produced in reading aloud prefixed words, specifically in acquired phonological or deep dyslexia, can be distinguished from errors produced with pseudo-prefixed words (e.g. *relate* [re-][late]) or with words containing word-final embedded stems (e.g. *suspend* [spend]), and can therefore considered to be purely morphological, similarly to what has been discussed for suffixed words (e.g. Funnell, 1987; Rastle et al., 2006). Castles, Coltheart, Savage, Bates, and Reid (1996), in an investigation of two English speakers, found morphological errors with prefixed words to be undistinguishable from errors with pseudo-prefixed words (unlike errors with suffixed words). Similar results are reported by Badecker and Caramazza (1987), who found errors with both prefixed and suffixed words to be indistinguishable from visual errors. In contrast, two other studies (Kay, 1988; and Hamilton & Coslett, 2008), each involving two English participants, found errors with both prefixed and suffixed to be dissociable from, respectively, errors with pseudo-prefixed and pseudo-suffixed words. Similar evidence, though only with prefixed words (suffixed and pseudo-suffixed words were not included), was also reported in Job and Sartori's (1984) case study involving an Italian native speaker. The authors additionally report that their participant produced fewer errors when reading illegal combinations of existing prefixes and stems, as well as illegal combinations of existing stems and suffixes, as compared to non-words composed of real affixes and non-existing stems, which was taken as further evidence for a level of morphological decomposition.

Note that none of these studies specifically focused on prefixed words, which were mostly investigated as an additional set of items among various experiments, with very few items per condition and no clear theory-driven predictions on why it is relevant to look at prefixed words. Furthermore, none of them, in their comparisons between truly prefixed and pseudo-prefixed items or items with embedded stems, controlled for all the variables that have been crucially shown to predict the occurrence of morphological errors, namely frequency and imageability of both the full forms and their stems (Funnell, 1987; Rastle et al., 2006). As for specific differences between prefixes and suffixes, none of these studies presented with clear predictions or with a discussion on how morphological impairments differ for prefixed and suffixed items. The study by Job and Sartori (1984) is the only one mentioning differences in how prefixes and suffixes were affected in the individual they report, in that fewer errors were produced with prefixes than suffixes. However, because the prefixes they tested were all derivational while the suffixes were all inflectional, their comparison of prefixes and suffixes is completely confounded with the type of morphology (inflectional or derivational), and therefore it is not interpretable.

1.3 Aims and objectives

The most prominent accounts of morphological decomposition predict that this mechanism operates in the same way for all kinds of complex words, including prefixed and suffixed words, irrespective of their characteristics. At the same time, the major accounts of the suffixing preference (Cutler et al., 1985; St. Clair et al., 2009) predict differences between prefixed and suffixed words. Current research on morphological processing and morphological impairments has gone beyond the bare notion of morphological decomposition and investigated a number of different languages and linguistic phenomena to test to what extent the efficacy of morphological decomposition is constrained by a word's specific linguistic properties. However, the majority of these studies have exclusively investigated the case of suffixed words or compound words, while the literature on prefixed words has focused on a more restricted set of linguistic phenomena and research questions.

From this picture, it becomes quite clear that, if we want to investigate to what extent the processing and impairment of prefixed words differs from that of suffixed words, we need to apply the same fine-grained comparisons that have been investigated for suffixed words. This will allow asking specific questions and test hypotheses that can be precisely measured, building on the more general predictions that can be derived, along the lines of Jakobson's (1941–1968) approach, from the two major accounts of the suffixing preference. These predictions were presented in the last paragraph of Section 1.1:

> «First, prefixed words should present with larger processing costs than suffixed words. Processing prefixed words may be particularly challenging for non-native speakers, for whom the learnability disadvantage of prefixed words may add to the larger processing demands. Finally, prefixed words should also be more affected in aphasia than suffixed words».

Based on the literature on morphological decomposition presented in Section 1.2, we can now derive, for each of the three predictions, more specific research questions, which can be empirically tested.

Let us start from the prediction that *prefixed words should present with larger processing costs than suffixed words*. This extends Jakobson's (1941–1968) approach from language acquisition – for which, as described in the section 'Child language acquisition', the literature already presents with relatively convincing findings on prefixed words – to the domain of *language processing*. Acquiring a language is necessarily linked to the ability to process the corresponding linguistic input (see e.g. Clahsen & Felser, 2006; Fodor, 1998). Investigating language *processing* therefore represents a natural extension of the approach that Jakobson originally proposed. Furthermore, this prediction is also directly connected to the processing account of the suffixing preference by Cutler et al. (1985).

We can first make this prediction more precise by specifying that the larger processing costs associated with prefixed words arise from the fact that accessing the stem is more effortful when this is in word-final position, which would cause a delay in stem access for prefixed words as compared to suffixed words. Then, we can restrict the domain of this prediction to visual word processing, i.e. a domain in which there is not necessarily a linear order in which letters are presented to the comprehender, especially given current models of edge-aligned stem recognition (Grainger & Beyersmann, 2017), which makes this prediction much less trivial and, consequently, more relevant to test. We have seen that the available findings on morphological decomposition of prefixed words in visual word processing are quite mixed, mostly depending on the type of task employed: while RT data from simple lexical decision experiments and eye-fixation data reveal differences between prefixed and suffixed words, it is also true that *all* masked priming experiments on (existing) prefixed words reported significant morphological priming effects for prefixed words, indicative of efficient morphological decomposition. What follows is that, if we want to investigate to what extent prefixed words present with larger processing costs in the early stages of processing that are tapped into by masked priming, we will need to look at more fine-grained comparisons. This can be done by investigating whether morphological decomposition of prefixed words is constrained by the linguistic properties of the stimuli, in the same way as it has been done with suffixed words. In masked priming, this would result in reduced priming effects with certain types of morphologically complex primes compared to others. This question is crucial because, as we have seen in the literature overview, linguistic constraints have been found to limit the efficacy of morphological decomposition in suffixed words, yet only in very specific cases: (i) with lexically restricted items, but only in the domain of inflection (e.g. Morris & Stockall, 2012; Neubauer & Clahsen, 2009; Pastizzo & Feldman, 2002; Rastle et al., 2015), and not for derived words (Silva & Clahsen, 2008); (ii) with inflected forms as compared to derived words, but only in L2 processing, and not in L1 processing (e.g. Silva & Clahsen, 2008; Jacob et al., 2018; Kirkici & Clahsen, 2013). Hence, what can be tested is whether such linguistic constraints limit the efficacy of morphological decomposition of prefixed words in a larger number of cases than for suffixed words. This leads to my first research question:

> **Research Question 1**. Is morphological decomposition of prefixed words constrained by a word's specific linguistic properties? More precisely:
>
> - **Research Question 1a**. Does morphological decomposition work as efficiently for prefixed derived words as for suffixed derived words, in both lexically unrestricted and lexically restricted derivations? (Publication I)
> - **Research Question 1b**. Are prefixed inflected words decomposed as efficiently as prefixed derived words? (Publication II)

Specifically, while lexical restrictedness does not affect morphological decomposition of *suffixed derived* words, it may have an effect on *prefixed derived* words. Similarly, with suffixed words, priming effects with inflected compared to derived primes are reduced only in non-native processing, but not in native processing; yet, the derivation versus inflection dichotomy may apply to prefixed words even in native processing. To address this question, I first investigated, in a group of German native speakers, masked morphological priming effects with prefixed and suffixed German derived words in two sets of items, namely lexically restricted and lexically unrestricted derivations (Publication I). The lexically restricted set of items included prefixes and suffixes (the negation prefix *in-* and the nominalization suffix *-ität*) that can be attached only to a specific subset of lexical items, i.e. foreign stems; the lexically unrestricted set included prefixes and suffixes (the negation prefix *un-* and the nominalization suffix *-keit*) that can be attached to both foreign and native stems. The design allowed testing: (i) whether early, pre-lexical morphological decomposition of prefixed words works as efficiently for lexically restricted as for lexically unrestricted items, by comparing the priming magnitude of lexically restricted and unrestricted items; (ii) whether early, pre-lexical morphological decomposition of prefixed derived words works as efficiently as in suffixed derived words, by directly comparing the priming magnitude with prefixed and derived primes, both lexically unrestricted and lexically restricted.

I then investigated priming effects with *prefixed inflected* words as compared to *prefixed derived* words (Publication II). This was done by exploiting the characteristics of Bantu languages, which offer the unique opportunity to test inflectional prefixes, otherwise virtually absent in Indo-European languages. The study specifically involved native speakers of Setswana, a Bantu language mostly spoken in Botswana and South-Africa. Priming from prefixed words was tested with both inflected primes (the plural prefix *di-*) and derived primes (the prefix *bo-*, which is used to transform a noun into another noun with a related, more abstract meaning). The unique comparison of derivational to inflectional prefixes, as well as the fact that the study was conducted on native speakers of an under-researched language represent innovative aspects of this study. In both publications, the critical comparisons were performed *on the same targets* and *in the same group*, which also represents an improvement to previous research on prefixed words.

The second general prediction was that *processing prefixed words may be particularly challenging for non-native speakers*. This extends Jakobson's (1941–1968) account from *first* language acquisition to *second* language acquisition, or more precisely second language *processing*. It is also based on the idea that the learnability disadvantage for prefixed words postulated by St. Clair et al. (2009) may add to the larger processing demands for prefixed words that Cutler et al. (1985) postulated. Again, we can restrict the prediction to the domain of the early stages of visual word recognition tapped into by masked priming. We have seen that, in first language acquisition, not only do children acquire prefixed words later than suffixed words (Clark, 2001; Kuczaj, 1979; Mithun, 1989; Slobin, 1973), but they also show effects of morphological decomposition later in life for prefixed than suffixed words (Hasenäcker et al., 2017). At the same time, we have seen that, in L2 speakers, reliable masked priming effects have been reported in the case of suffixed derived words (e.g. Silva & Clahsen, 2008; Jacob et al., 2018; Kirkici & Clahsen, 2013), but the only study investigating prefixed words in L2 speakers found that morphological priming effects were indistinguishable from orthographic effects (J. Li & Taft, 2019). Therefore, my second research question:

> **Research Question 2**. Can prefixed derived words be decomposed as efficiently in non-native processing as in native processing? (Publication I)

This question was investigated by comparing morphological priming effects of a group of proficient L2 speakers of German to those found in a group of L1 speakers (Publication I). We took advantage of the large Russian community living in the Potsdam and Berlin area, which was a particularly appropriate target group for the purposes of my dissertation for two reasons. First, Russian presents with similar derivational affixes to those included in our experimental design, which ensured that any L1-L2 difference that we may find cannot not be explained in terms of cross-linguistic differences between the L1 and L2 of the participants. Furthermore, this community includes a large number of highly proficient German speakers, which ensured that the speakers' knowledge of German vocabulary was good enough for participating in a lexical decision experiment. The experiment allowed answering the question about whether, for the early stages of visual word recognition, we have evidence for less efficient morphological decomposition (i.e. reduced priming effects) of prefixed derived words in the L2 group compared to the L1 group. Priming with derived words included both lexically unrestricted and lexically restricted affixes. As underlined above, priming with prefixed derived words was also compared to priming with suffixed derived words, measured on the same targets. This was the first study investigating *both* types of derived words in L2 processing, allowing for a direct comparison between priming with prefixed and suffixed derived primes. Particularly crucial for this research question was also the set of control items testing for effects of bare orthographic overlap, with both word-initially and word-finally overlapping primes, again on the same targets. This allowed checking if the priming effects that we would report for the L2 group were truly morphological in nature.

Finally, the third general prediction was that *prefixed words should be more affected in aphasia than suffixed words*. This is directly based on Jakobson's (1941–1968) hypothesis that the linguistic phenomena that are cross-linguistically less widespread are at the same time acquired later in first language acquisition and lost earlier in aphasia. While language acquisition and artificial language learning data on prefixes (e.g. Slobin, 1973; St. Clair et al., 2009) support Jakobson's hypothesis on language acquisition, no study has directly tested this hypothesis with regard to prefixed words in language loss. Following

St. Clair et al. (2009), the reason why suffixes are more prone to be learned than prefixes is that it is easier to learn the properties of the stem an affix encodes when this follows the stem than when it precedes it. This may also extend to how easily affixes are lost, with prefixes being more impaired than suffixes. Furthermore, prefixed words may also be overall more impaired than suffixed words because of a processing disadvantage in accessing word-final stems, as postulated by Cutler et al. (1985). In order to test how prefixed words are impaired in acquired language disorders, we can first restrict our focus to the domain of reading aloud, by investigating the errors produced with prefixed words in reading aloud tasks. This is a domain that presents a relatively large body of literature on suffixed words, mostly inflected, but also derived words (see Semenza & Mondini, 2015 for a review). Previous literature has shown that: (i) different types of complex words, such as inflected and derived suffixed words, may be affected differently in language loss (e.g. Miceli & Caramazza, 1988); (ii) suffixed words are decomposed into their constituent morphemes, as indicated by the finding that errors involving suffixes are distinguishable from visual errors (e.g. Rastle et al., 2006). As for prefixed words, no study has ever directly tested whether there are differences in how prefixed and suffixed words are impaired; furthermore, whether morphological errors with prefixed words are distinguishable from visual errors, which would be indicative of morphological decomposition of prefixed words, is fully unclear (e.g. Castles et al., 1996; Hamilton & Coslett, 2008; Job & Sartori, 1984). This brings us to my third research question:

> **Research Question 3**. Are prefixed and suffixed words affected in different ways in acquired morphological impairments? More precisely:

- **Research Question 3a**. Do the number and types of errors produced with prefixed words differ from those produced with suffixed words? (Publication III, IV)
- **Research Question 3b**. Are morphological errors produced with prefixed words distinguishable from visual errors? (Publication IV)

To answer this question, I investigated the errors produced in a reading aloud task by three individuals with acquired language impairment (Publication III, case series), as well as in a series of other reading aloud tasks additionally administered to one of the three individuals (Publication IV, case study). I tested whether dissociations between different types of complex words (reported e.g. for inflected versus derived words) can also be found for the contrast between prefixed and suffixed derived words, the prediction being that prefixed words should be more impaired. Specifically, I investigated the numbers and types of errors produced with prefixed and suffixed words (Publication III and IV); the most critical comparison was the number and types of errors directly involving prefixes versus suffixes. Errors were obtained from different sets of items, including sets of matched prefixed and suffixed words (e.g. *unschön* [un-][schön] 'not beautiful, ugly' vs. *machtlos* [macht][-los] 'powerless') and words containing both a prefix and a suffix (e.g. *Entwertung* [ent-][wert][-ung] 'devaluation'). I then investigated whether errors involving prefixes are truly morphological in nature (Publication IV), a question that was never thoroughly investigated in the literature on acquired morphological impairments. To this end, I compared errors with truly prefixed words (*ungleich* [un-][gleich] 'unequal') to errors with words containing word-final embedded stems (*Barock* 'baroque' contains *Rock* 'skirt/rock music'), including pseudo-prefixed words (*Inhalt* 'content' [in-][halt] contains *Halt* 'stop' and the pseudo-prefix *in-*). If numbers and types of morphological errors are found to differ for the different conditions (e.g. more morphological errors with prefixed words), this is taken as evidence for morphological decomposition. If not, we would have no evidence that prefixed word are decomposed, and morphological errors with prefixed words should just be interpreted as visual errors, which would represent another difference between the impairment of prefixed words and the impairment of suffixed words. The direct investigation of differences between prefixed and suffixed words and the investigation of whether errors with prefixed words rare genuinely morphological both represent innovative aspects of the two publications.

As compared to the largely investigated case of suffixed words, prefixed words have been comparably neglected in the research on morphological processing and morphological disorders. The investigations and results from the four manuscripts reported in the following chapters contribute to our knowledge of how morphological decomposition is affected by the specific properties a complex word, in this case for prefixed versus suffixed words, and thus to a better specification of current models of morphological processing during visual word recognition and reading aloud, as well as to a better understanding of the links between language universals, language processing in native and non-native speakers, and language loss. This was achieved by: (i) testing decomposition of German prefixed derived words in visual word recognition, with a design carefully conceived to directly compare prefixed derived words and suffixed derived words, as well as by adding a contrast of different types of derivations that had never been investigated in the literature on prefixed words (lexically restricted and unrestricted); (ii) additionally investigating whether proficient non-native speakers of German differ from L1 speakers in how efficiently prefixed words are decomposed, again by testing them on experimental manipulations that are new to the L2 literature; (iii) testing decomposition of prefixed words in Setswana, which not only is an under-researched language, but also offers the unique opportunity to test inflectional prefixation, a morphological phenomenon that was until now critically absent from the morphological processing literature; (iv) directly assessing, across different types of item sets, whether prefixed and suffixed words are impaired differently in language loss; (v) thoroughly examining for the first time in the literature the nature of morphological errors with prefixed words.

2. Overview of the publications

The experimental work of the thesis is presented in the form of four manuscripts, either published or under review. In the present chapter, I will provide an overview of the aims and results of the four manuscripts.

PUBLICATION I

First author; published in *Language Learning*, 2020.
DOI: https://doi.org/10.1111/lang.12370

Variability and consistency in first and second language processing: A masked morphological priming study on prefixation and suffixation

Authors: Laura Anna Ciaccio[1] and Harald Clahsen[1]

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Summary: The study investigated whether morphological decomposition of prefixed derived words works as efficiently as with suffixed words. We conducted a masked morphological priming experiment with German derived words with the aim of: (i) testing morphological priming effects with prefixed derived words, both lexically restricted (*inaktiv* 'inactive') and lexically unrestricted (*unsauber* 'not clean'), priming their corresponding stems (*aktiv* 'active', *sauber* 'clean'); (ii) directly comparing morphological priming effects for prefixed words to those obtained for suffixed primes, both lexically

restricted (*Aktivität* 'activity') and unrestricted (*Sauberkeit* 'cleanness'), by testing prefixed and suffixed words priming the same targets; (iii) assessing priming effects with prefixed and suffixed words in both a group of native (L1) and a group of non-native (L2) speakers of German. Our results showed efficient morphological decomposition of prefixed derived words, both lexically restricted and unrestricted. Furthermore, priming effects for prefixed words were similar in magnitude to priming effects with suffixed words. Finally, we obtained parallel results for the L1 and the L2 group. Morphological priming effects were, in both groups, dissociable from effects of orthographic or semantic relatedness. Taken together, our findings suggest that morphological decomposition of *derived* words works particularly robustly, irrespective of a word's specific properties and of the speakers' language status. By comparing these findings to results from previous masked-priming research on *inflection* and *compounding*, we finally proposed an account of morphological decomposition that captures both the variability and the consistency of the early stages of morphological decomposition for different types of complex words and groups of speakers.

Personal contribution: I contributed to conceiving the experimental set-up. I designed and programmed the experiment. I conducted all experimental sessions with participants, performed the statistical analyses of the data, and contributed to data interpretation. I wrote the first full draft of the manuscript and contributed to editing and finalizing the manuscript.

Contribution of co-authors: Harald Clahsen was involved in the conception of the experimental set-up, as well as in the interpretation of the data. He additionally contributed to writing sections of the manuscript, particularly the introduction and discussion sections, and to editing and finalizing the manuscript.

PUBLICATION II

First author; published in *Language, Cognition and Neuroscience*, 2020.
DOI: https://doi.org/10.1080/23273798.2020.1722847

Morphological decomposition in Bantu:
A masked priming study on Setswana prefixation

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Summary: The study investigated masked morphological priming effects in a Bantu language, Setswana. We took advantage of the rich system of prefixes in Bantu languages, which offers the opportunity of testing morphological priming effects with prefixed inflected words, a linguistic phenomenon that was until now undocumented in the morphological processing literature. We tested masked morphological priming effects with prefixed inflected primes (*dikgeleke* 'experts') and additionally compared them to priming effects obtained with prefixed derived primes (*bokgeleke* 'talent') on the same target words (*KGELEKE* 'expert'). We found significant priming effects of similar magnitude with both prefixed inflected and prefixed derived words. These findings are compatible with a mechanism of morphological decomposition that operates during the early stages of visual word recognition and segments both prefixed inflected and prefixed derived words into its constituents, in line with what has been previously reported for

other types of complex words. However, we additionally reported unexpected results from control sets testing priming with suffixed words and with primes overlapping orthographically (word-initially) with their targets. We thus argued that current models of morphological decomposition cannot account for the whole spectrum of our findings.

Personal contribution: I contributed to conceiving the experimental set-up and to designing and programming the experiment. I performed the statistical analyses of the data and contributed to data interpretation. I wrote the first full draft of the manuscript and contributed to editing and finalizing the manuscript.

Contribution of co-authors: Naledi Kgolo was involved in conceiving the experimental set-up, designing, and programming the experiment, as well as in the interpretation of the data. She conducted all experimental sessions with participants. She also contributed to writing the sections of the manuscript concerning the linguistic background on Setswana and the description of the materials. She was finally involved in editing and finalizing the manuscript. Harald Clahsen was involved in the conception of the experimental set-up, as well as in the interpretation of the data. He additionally contributed to writing the discussion section, and to editing and finalizing the manuscript.

PUBLICATION III

First author; published in *Frontiers in Psychology*.

DOI: https://doi.org/10.3389/fpsyg.2020.01070

Derivational morphology in agrammatic aphasia:

A comparison between prefixed and suffixed words

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Summary: The study investigated how prefixed derived words are impaired in acquired morphological impairments, as compared to suffixed words. We analyzed the errors produced in a reading aloud task by three German individuals with agrammatic aphasia (NN, LG, SA). The task included prefixed derived words (e.g. *unreif* [un-][reif] 'immature'), suffixed derived words (*machtlos* [macht][-los] 'powerless'), and matched simple words (e.g. *Pfeffer* 'pepper'). We first focused on the overall error rates in three conditions. We then further analyzed the types errors produced with prefixed and suffixed words, focusing on errors affecting affixes (rates of affix errors) and errors affecting stems (rates of errors on stem). Concerning the overall error rates, we reported

that NN, in line with the characteristics of morphological impairments, produced overall more errors with both prefixed and suffixed words as compared to simple words, with no difference between the two. Nevertheless, by specifically looking at the rates of affix errors he produced, we found more affix errors with prefixes than with suffixes. SA, instead, showed a selective impairment for prefixed words both in the overall error rates, with prefixed words eliciting larger error rates than both simple and suffixed words, and in the rates of affix errors, with more affix errors on prefixes than on suffixes. Instead, LG did not show the typical symptoms of a morphological impairment, since he produced equal number of errors in all conditions and very few affix errors. Concerning the rates of errors on stems, no relevant difference between prefixed and suffixed words was detected. We explained the difference between prefixed and suffixed words in the number of affix errors, reported for NN and SA, in terms of the specific properties encoded by prefixes and suffixes, which makes prefixes more prone to be affected by language loss.

Personal contribution: I contributed to conceiving the experimental set-up. I designed and programmed the experiment. I conducted all experimental sessions with participants, performed the statistical analyses of the data, and interpreted the data. I wrote the first full draft of the manuscript and contributed to editing and finalizing the manuscript.

Contribution of co-authors: Carlo Semenza and Frank Burchert were involved in the conception of the experimental set-up and in the interpretation of the data. They additionally contributed to editing and finalizing the manuscript.

PUBLICATION IV

First author; under review in *The Mental Lexicon*.

Morphological errors in acquired dyslexia: The case of prefixed words

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Summary: The study provides an investigation of the nature of morphological errors produced in reading aloud prefixed derived words by a German individual with agrammatism and acquired dyslexia (NN). In Experiment 1, we replicated previous findings of overall larger error rates with prefixed words as compared to simple words. In Experiment 2, we investigated whether morphological errors (i.e. errors on affixes) in prefixed words (e.g. *ungleich* [un][gleich] 'unequal') are distinguishable from visual errors produced with items containing stems embedded word-finally ('final embedding condition'), such as *Gazelle* 'gazelle' (which contains *Zelle* 'cell'). We reported different error patterns for prefixed and 'final embedding' items, suggesting that NN's morphological errors with prefixed words cannot be explained in terms of visual errors. Because NN never produced any semantic error, we additionally ruled out that his

morphological errors are semantic in nature, and therefore concluded they they must be genuinely morphological. By comparing morphological errors produced with prefixed words to errors produced with an additional set of suffixed words (e.g. *kalkig* [kalk][ig] 'limy'), we additionally found that suffixes were exclusively substituted, while prefixes were rather omitted. In Experiment 3, we replicated this asymmetry in the impairment of prefixes versus suffixes in a different set of items, which consisted of three-morphemic words including both a prefix and a suffix (e.g. *Entgiftung* [ent][gift][ung] 'detoxification'). This was taken to indicate that the specific properties of derivational prefixes and suffixes affect how they impaired in language loss.

Personal contribution: I contributed to conceiving the experimental set-up. I designed and programmed the experiment. I conducted all experimental sessions with the participant, performed the statistical analyses of the data, and interpreted the data. I wrote the first full draft of the manuscript and contributed to editing and finalizing the manuscript.

Contribution of co-authors: Carlo Semenza and Frank Burchert were involved in the conception of the experimental set-up and in the interpretation of the data. They additionally contributed to editing and finalizing the manuscript.

3. Publication I

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Variability and consistency in first and second language processing: A masked morphological priming study on prefixation and suffixation

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ABSTRACT

Word forms such as *walked* or *walker* are decomposed into their morphological constituents (walk + −ed/−er) during language comprehension. Yet, the efficiency of morphological decomposition seems to vary for different languages and morphological types, as well as for first and second language speakers. The current study reports results from a visual masked priming experiment focusing on different types of derived word forms (specifically prefixed vs. suffixed) in first and second language speakers of German. We compared the present findings with results from previous studies on inflection and compounding and proposed an account of morphological decomposition that captures both the variability and the consistency of morphological decomposition for different morphological types and for first and second language speakers.

Keywords: prefixed words; derivation; second language processing; masked priming; morphology

INTRODUCTION

Much research in linguistics has focused on what is common (perhaps even universal) across different languages and among different speakers of a language. At the same time, variability due to geographical or social factors, for example, is also a hallmark of language and language use. Variability may even occur within a single speaker depending on the context in which language is used. Yet, variability in language and language performance is limited by such factors as linguistic and cognitive constraints.

Psycholinguistic research faces the same challenge of disentangling variability in language production and comprehension from more general (perhaps universal) mechanisms of language processing. Consider a well-known finding from experimental research on morphologically complex words: A range of studies examining both derived (*player*) and inflected (*played*) word forms have provided support for an automatic decomposition mechanism that segments these word forms into their morphological constituents (for a review, see Marslen-Wilson, 2007). This mechanism is supposed to be ubiquitous, operating across different languages and types of morphologically complex words (Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Rastle, Davis, & New, 2004). Yet, the efficiency with which morphological decomposition operates may vary depending on both linguistic properties of the complex forms involved and for different groups of speakers. To take an example, Jacob, Heyer, and Veríssimo (2018) found priming effects indicative of morphological decomposition to be reduced in second language (L2) speakers (despite advanced levels of L2 proficiency), but only for inflected words, not derived, whereas native (L1) speakers showed parallel decomposition effects for both morphological processes. Here we distinguish between morphological processes (such as derivation, inflection, and compounding) and morphological types (such as prefixed vs. suffixed word forms).

One approach of dealing with this kind of variability is through specialization, that is, by developing models of language processing — in the present case, accounts of morphological decomposition — that hold for L1 speakers only. Such models may be detailed and precise, and they have a clearly defined scope. Indeed, current psycholinguistic models in this domain are essentially accounts of L1 morphological processing based on experimental studies with adult L1 speakers (for a review, see Amenta & Crepaldi, 2012). The present study pursues a different approach by developing an account of morphological decomposition that includes evidence from both L1 and L2 speakers aimed at capturing both linguistic and group-level sources of variability of morphological decomposition. To this end, we employed the visual masked priming technique to investigate derived words of German representing different morphological types (namely, prefixed and suffixed forms) with different degrees of productivity and in groups of L1 and L2 speakers.

BACKGROUND LITERATURE

The idea of an early, obligatory decomposition mechanism operating on morphologically complex words originated from Taft and Forster (1975). The experimental technique that has mostly been used in recent years to investigate this mechanism is masked priming, which is believed to tap into early, prelexical stages of visual word recognition. In a masked priming experiment, participants typically perform a word/nonword (lexical) decision task on a visually presented target word that is preceded by a visual mask and a prime word, the latter of which is presented only briefly (between 30 and 70 milliseconds) to ensure that it is not consciously visible. When primes and targets are morphologically related to each other (e.g., *player–play*), target lexical decision times are normally faster, indicating facilitated recognition (priming) compared to an unrelated control condition (e.g., *lower–play*). Facilitation in such cases is attributed to morphological decomposition of the prime word ({play} –er), thereby isolating its morphological constituents, which then directly facilitates recognition of the target word *play*.

For derived word forms, a considerable number of masked priming studies have reported significant morphological priming effects in visual masked priming experiments for different languages. The vast majority of these studies have investigated English, for which morphological decomposition of derived words has been shown to work efficiently not only in adult L1 speakers (e.g., Rastle et al., 2004), but also in L2 speakers (e.g., Silva & Clahsen, 2008) and in children (e.g., Beyersmann, Castles, & Coltheart, 2012). Similarly, German derived words were shown to yield robust morphological priming effects in both L1 and L2 adults (Jacob et al., 2018) and in German children (Hasenäcker, Beyersmann, & Schroeder, 2016). In French, Quémart, Casalis, and Colé (2011) reported significant masked priming effects with derived words in adults and children. Similar findings have also been reported for adult L1 speakers of Russian (Kazanina, Dukova-Zheleva, Geber, Kharlamov, & Tonciulescu, 2008), Japanese (Clahsen & Ikemoto, 2012), and Korean (Kim, Wang, & Taft, 2015). Together, the evidence from these studies suggests that early, prelexical morphological decomposition represents a widespread (perhaps universal) mechanism of processing derived words.

The efficacy with which morphological decomposition of derived words operates may, however, be affected by the specific linguistic properties of complex words, for example, by whether a complex word is prefixed or suffixed. While many studies have found morphological decomposition effects for suffixed words, it is less clear whether this holds for prefixed words. A number of studies employing unprimed lexical decision tasks found differences between how prefixed and suffixed words are processed. Hasenäcker, Schröter, and Schroeder (2017) found that children show effects of morphological decomposition for prefixed words later than for suffixed words. For L1 adults, Ferrari Bridgers and Kacinik (2017) reported that prefixed words take longer to process than suffixed words. Likewise, Bergman, Hudson, and Eling (1988) showed that lexical decision times in response to suffixed and pseudosuffixed words are similar, but pseudoprefixed words take longer to recognize than prefixed words, which suggests that stem access is automatic only in suffixed words. Colé, Beauvillain, and Segui (1989) found that suffixed words with high cumulative root frequency were recognized faster than those with low cumulative root frequency, whereas there was no such effect for prefixed words. Similar results were also found in eye movement monitoring. Beauvillain (1996) reported root frequency to affect fixation durations in suffixed but not in prefixed words, indicating that prefixed words are less efficiently decomposed down to the root than suffixed words.

On the other hand, studies that have employed masked priming have consistently found priming effects for derived words with prefixes, suggestive of prelexical decomposition for these word forms (Diependaele, Sandra, & Grainger, 2009; Forster & Azuma, 2000; Grainger, Colé, & Segui, 1991; Heide, Lorenz, Meinunger, & Burchert, 2010; Kazanina, 2011; Kim et al., 2015). Masked priming effects have also been reported for prefixed and suffixed pseudowords, that is, combinations of existing affixes and stems that result in (nonexisting) pseudowords, for example, *love* + *dom*. The results were mixed, however. Some researchers reported parallel priming effects for prefixed and suffixed pseudowords (Beyersmann, Cavalli, Casalis, & Colé, 2016; Heathcote, Nation, Castles, & Beyersmann, 2018; Mousikou & Schroeder, 2019), others showed priming for suffixed but not for prefixed pseudowords (Kim et al., 2015). Except for Beyersmann et al.'s (2016) study of pseudowords, there are (to our knowledge) no masked priming studies that directly compared prefixed and suffixed prime words on the same targets and in the same participants. Hence, the question of whether prefixed words can be decomposed prelexically as efficiently as suffixed words is still open.

Another linguistic source of variability for morphological decomposition is lexical restrictedness, that is, whether or not a morphological process applies to a limited set of lexical items. For irregular inflection, for example, reduced masked priming effects have been reported, relative to lexically unrestricted, regularly inflected words (Neubauer & Clahsen, 2009). For derivation, on the other hand, masked priming experiments (Silva & Clahsen, 2008) revealed parallel masked priming effects for both lexically restricted and unrestricted forms (*-ness* vs. *-ity*).

Language processing has also been shown to exhibit variability depending on an individual's working memory, vocabulary size, reading speed, and other factors (e.g., Borovsky, Elman, & Fernald, 2012; Hopp, 2014, 2015). Morphological decomposition in particular has been found to be influenced by an individual's spelling and vocabulary abilities (Andrews & Lo, 2013). Furthermore, whether a particular language represents an individual's L1 or a L2 has also been reported to influence morphological decomposition. A number of previous studies found that despite having reached a high level of proficiency in a given language, L2 speakers may show reduced masked priming effects relative to L1 speakers, particularly for regularly inflected word forms (Jacob et al., 2018; Kirkici & Clahsen, 2013; Silva & Clahsen, 2008). Furthermore, L2 processing of morphologically complex words has been found to be more susceptible to surface form prime–target overlap than L1 processing. Unlike L1 control groups, advanced bilinguals showed significant priming effects for orthographically related items in a number of masked priming experiments (Diependaele, Duñabeitia, Morris, & Keuleers, 2011; Feldman, Kostić, Basnight-Brown, Đurđević, & Pastizzo, 2010; Heyer & Clahsen, 2015; J. Li, Taft, & Xu, 2017; M. Li, Jiang, & Gor, 2017).

Taken together, while previous research has shown pervasive effects of morphological decomposition during word recognition, there are also indications that the efficiency with which this mechanism functions varies across different languages, different morphological types, and among L1 and L2 speakers. However, the details and limits of this variability are still largely unknown. Against this background, the current study aims to account for both the variability and consistency of morphological decomposition for different morphological types and for L1 and L2 speakers. To this end, we report results from a masked priming experiment with derived words and, in the discussion section, compare the present findings to previous studies of morphological decomposition in inflected words and compounds.

THE PRESENT STUDY

The experiment reported below investigated the processing of derived word forms in highly proficient late bilingual speakers of German with Russian as their L1, as well as a control group of L1 German speakers. The linguistic phenomena under study are prefixed negated adjectives and deadjectival nominalizations with suffixes, which included forms such as *unsauber* 'not clean' and *Sauberkeit* 'cleanness'. German derivation has a large inventory of prefixes and suffixes to form derived adjectives, nouns, and adverbs. For some derivational processes, German offers lexically restricted (+R) affixes that apply to non-Germanic words of, for example, Latinate or Greek origin, and lexically unrestricted (−R) affixes which may appear on both Germanic and non-Germanic stems (for the same phenomenon in English, see Aronoff, 1976). The two derivational processes we selected for this study included both (+R) and (−R) affixes, namely, the prefixes *un–* and *in–* (e.g., *unsauber* 'not clean', *inaktiv* 'inactive') and the suffixes *-keit* and *–ität* (e.g., *Sauberkeit* 'cleanness', *Aktivität* 'activity').

With regard to negated adjectives, while both prefixes have the same function (in that they form the antonym of the stem to which they are attached), the (−R) affix *un−* can be used in combination with any stem, including non-Germanic stems (e.g., *untypisch* 'atypical', *unproduktiv* 'unproductive'), whereas the (+R) affix *in−* only occurs on non-Germanic stems. Deadjectival nominalizations offer the same (±R) contrast for suffixed forms. Both *−keit* and *−ität* derive a noun from an adjective that denotes the property expressed by the adjective. However, the suffix *−keit* (at least in its variant *−heit*) is (−R) in that it occurs on both Germanic and non-Germanic stems (cf. *Gesundheit* 'health' and *Diszipliniertheit* 'disciplinedness'). By contrast, the suffix *−ität* (+R) is restricted to non-Germanic stems (for further details, see Fleischer & Barz, 2007, pp. 65–66 and 269–274).

With materials constructed from these two phenomena, it was possible to measure morphological priming effects for prefixed and suffixed forms on the same targets, which allowed for direct comparisons of priming effects from the two types of derived words (prefixation, suffixation) for both −R and +R affixes. Example 1 illustrates a stimulus set in the morphological priming conditions. In addition, we included orthographic priming conditions, with both word- initial and word-final overlap, as shown in Example 2, and a semantic priming condition, as shown in Example 3.

Example 1. Morphological priming

(−R) *unsauber—sauber*	*Sauberkeit—sauber*
'not clean'—'clean'	'cleanness'—'clean'
(+R) *inaktiv—aktiv*	*Aktivität—aktiv*
'inactive'—'active'	'activity'—'active'

Example 2. Orthographic priming

Tutor—Tor	*Tortur—Tor*
'tutor'—'gate/goal'	'torture'—'gate/goal'

Example 3. Semantic priming

Herd—Pfanne

'stove'—'pan'

If morphological decomposition in a L2 works less efficiently, L2 speakers should show smaller priming effects than L1 speakers. Furthermore, if prefixed words are only decomposed postlexically, they should yield reduced priming effects compared to suffixed words. Likewise, if lexical restrictedness reduces decomposability, lexically restricted forms (+R) should yield smaller masked priming effects than (−R) forms.

METHOD

Participants

Forty-eight L1 speakers (37 women) and 48 L2 speakers (43 women) of German took part in the experiment in exchange for payment or course credits. Participants in the two groups had similar ages (M_{age} L1 = 25.46 years, *SD* = 4.13, *range* = 18–34; M_{age} L2 = 26.04 years, *SD* = 4.82, *range* = 20–41), and levels of education ranging from high school diploma to university degrees (L1: 28 high school, 1 vocational training, 19 university degree; L2: 14 high school, 34 university degree). All participants in the L2 group were native speakers of Russian; eight of them spoke Ukrainian (7) or Azerbaijani (1) as their additional mother tongue. They all learned German after the age of 6 (M_{age} = 13.02 years, *SD* = 5.46, *range* = 6–24), 20 of them as their first foreign language (two of which simultaneously with another language), 27 as their second foreign language, and one as her fifth language. They all lived in Germany at the time of testing, having arrived in Germany at a mean age of 18.94 years (*SD* = 6.81, *range* = 7–35), and reported using

German, both written and spoken, on a regular basis, with a mean use of written German of 50.6% (*SD* = 21.3, *range* = 6–95) and a mean use of spoken German of 50.3% (*SD* = 19.7, *range* = 13–95). The L2 participants' skills in German were assessed using a 30-item multiple-choice test developed by the Goethe Institute (https://www.goethe.de/de/spr/kup/prf/prf.html). Only participants who achieved a score corresponding to the levels B2, C1, or C2 of the Common European Framework of Reference for Languages (Verhelst, Van Avermaet, Takala, Figueras, & North, 2009) were recruited for the study. B2 represents the upper rank of the so-called 'independent user' level, and C1 and C2 refer to the two ranks of the 'proficient user' level. The L2 group achieved a mean score of 25.31/30 (*SD* = 3.07, *range* = 19–30), corresponding to a mean level of C1 (*range* = B2–C2).

Materials

Critical items. We selected all items, together with their (base 10 log-transformed) lemma and word form frequency per million, from the webCELEX database (http://celex.mpi.nl). Tables 1 and 2 provide prime and target characteristics for all experimental sets. Following Sassenhagen and Alday's (2016) suggestion, these tables report information about matching for the selected variables through descriptive rather than inferential statistics[1]. A complete list of the stimuli is available in Appendix S1 in the Supporting Information online.

Table 1. Characteristics of primes in each set.

Set/Prime type	Statistic	LF	WFF	Letters	Syllables	Overlap
−R/Prefixed	*M* (*SD*)	0.22 (0.33)	0.13 (0.26)	9.75 (1.48)	3.17 (0.39)	0.90 (0.02)
	95% CI	[0.01, 0.43]	[−0.03, 0.30]	[8.81, 10.69]	[2.92, 3.41]	[0.89, 0.91]
−R/Suffixed	*M* (*SD*)	0.26 (0.35)	0.26 (0.35)	11.75 (1.48)	3.42 (0.51)	0.90 (0.02)
	95% CI	[0.04, 0.48]	[0.04, 0.48]	[10.81, 12.69]	[3.09, 3.74]	[0.89, 0.91]
−R/Unrelated	*M* (*SD*)	0.28 (0.37)	0.14 (0.27)	9.58 (1.16)	3.50 (0.52)	–
	95% CI	[0.04, 0.51]	[−0.04, 0.31]	[8.84, 10.32]	[3.17, 3.83]	–
+R/Prefixed	*M* (*SD*)	0.00 (0.00)	0.00 (0.00)	9.25 (1.48)	3.75 (0.62)	0.89 (0.02)
	95% CI	[0.00, 0.00]	[0.00, 0.00]	[8.31, 10.19]	[3.36, 4.14]	[0.88, 0.90]
+R/Suffixed	*M* (*SD*)	0.45 (0.57)	0.45 (0.55)	11.25 (1.48)	4.75 (0.62)	0.85 (0.06)
	95% CI	[0.09, 0.82]	[0.09, 0.80]	[10.31, 12.19]	[4.36, 5.14]	[0.81, 0.89]
+R/Unrelated	*M* (*SD*)	0.36 (0.46)	0.22 (0.37)	9.67 (1.61)	3.92 (0.67)	–
	95% CI	[0.07, 0.66]	[−0.02, 0.46]	[8.64, 10.69]	[3.49, 4.34]	–
Orthographic/Word final	*M* (*SD*)	0.36 (0.60)	0.27 (0.47)	6.50 (1.00)	2.00 (0.43)	0.87 (0.08)
	95% CI	[−0.01, 0.74]	[−0.03, 0.58]	[5.86, 7.14]	[1.73, 2.27]	[0.82, 0.92]
Orthographic/Word initial	*M* (*SD*)	0.97 (0.57)	0.80 (0.59)	6.50 (1.51)	2.33 (0.78)	0.87 (0.08)
	95% CI	[0.6, 1.33]	[0.42, 1.17]	[5.54, 7.46]	[1.84, 2.83]	[0.81, 0.92]
Orthographic/Unrelated	*M* (*SD*)	0.66 (0.54)	0.43 (0.53)	6.42 (1.24)	2.33 (0.49)	–
	95% CI	[0.32, 1.00]	[0.10, 0.77]	[5.63, 7.2]	[2.02, 2.65]	–
Semantic/Related	*M* (*SD*)	0.96 (0.58)	0.67 (0.52)	5.89 (1.69)	1.89 (0.60)	–
	95% CI	[0.52, 1.41]	[0.28, 1.07]	[4.59, 7.19]	[1.43, 2.35]	–
Semantic/Unrelated	*M* (*SD*)	0.71 (0.48)	0.42 (0.37)	6.33 (1.50)	2.11 (0.78)	–
	95% CI	[0.34, 1.08]	[0.14, 0.70]	[5.18, 7.49]	[1.51, 2.71]	–

Note. LF = lemma frequency; WFF = word form frequency; Overlap = orthographic overlap between prime and target.

Table 2. Characteristics of targets in each set.

Set	Statistic	LF	WFF	Letters	Syllables	Overlap
–R	*M* (*SD*)	0.83 (0.44)	0.44 (0.48)	7.75 (1.48)	2.17 (0.39)	0.83 (0.44)
	95% CI	[0.55, 1.11]	[0.13, 0.74]	[6.81, 8.69]	[1.92, 2.41]	[0.55, 1.11]
–R	*M* (*SD*)	0.68 (0.57)	0.36 (0.52)	7.25 (1.48)	2.75 (0.62)	0.68 (0.57)
	95% CI	[0.32, 1.05]	[0.03, 0.69]	[6.31, 8.19]	[2.36, 3.14]	[0.32, 1.05]
Orthographic	*M* (*SD*)	1.23 (0.50)	0.97 (0.52)	3.58 (0.79)	1.08 (0.29)	1.23 (0.50)
	95% CI	[0.92, 1.55]	[0.64, 1.30]	[3.17, 4.16]	[0.90, 1.27]	[0.92, 1.55]
Semantic	*M* (*SD*)	0.96 (0.58)	0.67 (0.52)	5.56 (1.13)	1.89 (0.60)	0.96 (0.58)

Note. LF = lemma frequency; WFF = word form frequency; Overlap = orthographic overlap between prime and target.

Morphological priming was tested with both lexically unrestricted (–R) and lexically restricted (+R) affixes. For the –R set, we extracted from the webCELEX database adjectives that permit both a negated derived form with the prefix *un–* and a derived nominalization with the suffix *–keit*. Similarly, for the +R set, we extracted adjectives from the database that permit both a negated prefixed derivation with the prefix *in–* and a suffixed nominalization with *-ität*. In this way, we ensured that prefixation and suffixation priming effects were measured on the same stems. The 12 targets in the –R set were thus paired with three types of primes: (a) a negated adjective with the prefix *un–*, (b) a deadjectival noun with the suffix *–keit*, and (c) a matched unrelated control prime. Unrelated primes were dissimilar in form or meaning to their corresponding targets. Half of the unrelated primes were nouns and half were adjectives. All primes were matched as closely as possible for lemma and word form frequency and for number of syllables. Similarly, the 12 targets of the lexically restricted set (+R) were paired with a prefixed (*in–*), a suffixed (*-ität*), and an unrelated prime. All primes were matched for lemma and word form frequency; matching in terms of number of syllables was not possible for the +R items, as *-ität* is bisyllabic and *in–* monosyllabic. There were

72 prime–target pairs in the two morphological sets (–R, +R) for each list, with 12 pairs for each of the three prime types.

The items selected for the two sets (–R vs. +R) were matched as closely as possible to allow for comparisons between them. The targets for the two sets had similar word form frequencies, lemma frequencies, and length. Because foreign words (for the –R condition) are typically longer than native German words, we decided to include some targets in the –R set that are morphologically complex. However, care was taken to ensure that none of the selected target words incurred any bracketing paradoxes (e.g., Spencer, 1988). Consider, for example, the target *gastlich* 'hospitable' derived from the noun *Gast* 'guest'. In this case, *un*– can be attached to the derived adjective *gastlich* but not to *Gast*, hence bypassing a bracketing paradox. Furthermore, the different primes (prefixed, suffixed, unrelated) were held as parallel as possible in the two sets (±R) in terms of length and frequency.

Control items. We additionally created two control sets to determine to what extent priming effects for the two morphological sets are due to orthographic or semantic prime–target overlap. As in the morphological sets, the 12 target words of the orthographic set are orthographically fully contained in their related primes. To create this set, we selected from the webCELEX database pairs of simple words overlapping orthographically, but not morphologically or semantically, so that the target word was fully embedded in the prime word (similar to the morphologically related pairs). Each target was combined with an unrelated prime and two related primes, one in which the targets were embedded word finally and one in which they were embedded word initially, mimicking the prefixed and suffixed prime–target pairs from the morphological sets (e.g., *Tortur*–*Tor* 'torture–gate/goal' and *Tutor*–*Tor* 'tutor–gate/goal'). There were 12 prime–target pairs for each type of prime in each list. Targets and primes of the orthographic set were nouns and adjectives, and all primes were matched for lemma and word form frequency as well as number of letters and syllables.

For all related prime–target pairs in the morphological and orthographic sets, we computed the prime–target orthographic overlap ratio by using the Spatial Coding option in Davis's (2000) Match Calculator. The prefixed and suffixed primes in the −R set had the same amount of overlap to their target despite being different in length (see Table 1) because, in both cases, the prime fully contained the target, which is what this measure captures. The same is true for word-initial and word-final orthographically overlapping prime–target pairs while, in the case of +R items, the overlap was slightly lower for the suffixed primes because four of them contained a letter change in the stem (e.g., Flexibilität 'flexibility'–*flexibel* 'flexible'). Although it was not possible to select items in the orthographic set that were matched in length to the corresponding items in the morphological sets (because longer words in German tend to be morphologically complex), the pairs in the morphological and orthographic sets were matched for orthographic overlap. Furthermore, targets as well as related and unrelated primes were selected from a similar frequency range as those in the morphological sets.

For the semantic control set, we selected semantically related prime–target pairs that were morphologically unrelated, but were instead semantic associates and antonyms, thus mimicking the semantic relationships between suffixed prime–target pairs and between prefixed prime–target pairs (e.g., *Herd–Pfanne* 'stove–pan', *fleißig–faul* 'diligent–lazy'). The targets in the semantic set were as closely matched as possible to those of the two morphological sets in terms of lemma and word form frequency. The semantically related and unrelated primes were matched to each other for lemma and word form frequency and length in syllables and letters. There were 12 prime–target pairs each for two prime types (related, unrelated)[2]. As a semantic relatedness measure, we conducted an online survey in which 30 native speakers of German rated both the related and the unrelated prime–target pairs with respect to how similar in meaning the two words are on a 1–7 scale (with 1 as the lowest degree of similarity). The survey confirmed that each semantically related pair received a higher semantic similarity rating (M = 4.62, SD = 1.08) than its corresponding semantically unrelated pair (M = 1.29, SD = 0.14).

Experimental lists. Experimental lists were created following a Latin Square design. There were three blocks of items such that each block contained each target from the morphological and orthographic sets with a different prime type (prefixed/word-final overlap, suffixed/word-initial, unrelated). Targets from the semantic control set were distributed over two of these three blocks, as this set had only two prime types (related, unrelated). We then constructed three experimental lists, each with a different order of blocks, to control for effects of presentation order of each target with a specific prime. We finally created three additional lists with the reversed item order—to counterbalance for training or fatigue effects—resulting in six experimental lists in total.

The 132 experimental prime–target pairs in each list were mixed with 468 unrelated prime–target filler pairs, for a total of 600 trials. All trials were distributed across the lists in a pseudorandomized order, with three to five fillers occurring between two successive experimental targets. Of the fillers, 300 were nonwords, so that 'no' responses were required in half of the trials. Nonwords were created replacing one to three graphemes of existing German words. Adjectives, nouns, verbs, and adverbs were evenly distributed across the fillers. In total, 13.83% of all trials in each list consisted of related prime–target pairs.

Procedure

We tested all participants in a quiet laboratory room and randomly assigned them to one of the six presentation lists. Participants' reaction times (RTs) in milliseconds were measured using the experimental software DMDX (Forster & Forster, 2003). Participants were informed that they would see a sequence of existing German words and invented words in the center of the computer screen, and that they would have to decide as quickly and accurately as possible whether or not the target word was an existing word of German. The lexical decisions were performed by pressing one of two different buttons on a gamepad connected to the computer. 'Yes' responses were always elicited with the participants' dominant hand. Each trial started with a 500-millisecond blank screen. This was followed by a forward mask consisting of a number of hashes equal to the number of letters of the prime. Next, the prime was presented for 50 milliseconds, directly followed by the target. The target was displayed until the participant pressed the yes or no button, or otherwise disappeared after 500 milliseconds, with the screen turning blank. The maximum time allowed for the lexical decision was 5,000 milliseconds after presentation of the target. The next trial began right after the lexical decision, or after the (5 second) timeout.

Data analysis

The experiment yielded accuracy and RT data. The accuracy data were analyzed using a binary logistic regression model. For the RT data, timeouts and incorrect responses were excluded from all subsequent analyses (L1 = 4.91%, L2 = 7.75% of the experimental items). The remaining RT data were then log-transformed to normalize their distribution and reduce the influence of outliers (Ratcliff, 1993). Responses above and below two and a half standard deviations from each participant mean log RT across all correct trials were considered outliers and therefore also removed (L1 = 1.01%, L2 = 0.95% of the remaining experimental items). The log RT data were then analyzed in a series of mixed-effect linear regression models using the software R (Version 3.3.2; R Core Team, 2014).

All models were fitted using the package lme4 (Bates, Mächler, Bolker, & Walker, 2015). Parameters were estimated with restricted maximum likelihood. Depending on what a given model was supposed to test, a combination of the factors Group (L1, L2), Set (+R, −R), Relatedness Type (morphological, orthographic, semantic), Prime Type (e.g., prefixed, suffixed, unrelated), and their interactions were included as fixed effects. All contrasts for these fixed effects were computed from the generalized inverse function (Schad, Hohenstein, Vasishth, & Kliegl, 2018) so that the models would show main effects for each of the levels (e.g., prefixed Prime Type) across, for example, different sets or groups as compared to the level that was selected as baseline. All models included random intercepts for subjects and targets. For each analysis, we selected the best-fit model by adopting a bottom-up approach, starting from an intercept-only model. The initial model was expanded stepwise, by testing for inclusion of the following additional (centered) continuous predictors: (a) Block, to account for repetition effects of the targets (coded as 1–3 for the morphological and orthographic sets and as 1–2 for the semantic set, because targets were only repeated twice); (b) Prime Letters, to account for the consistently different length of the primes (in letters) across prime types and sets; and (c) Skill in German as interacting with Prime Type (in the models including only L2 speakers), to test whether the priming effects found for this group were modulated by the speakers' skill of L2 German (as measured through the Goethe Institute test). Additional fixed effects were only included if they significantly improved the model fit, as tested by the R anova function comparing the models with and without the additional predictor, with parameters being estimated for maximum likelihood.

Once we determined the best fixed-effect structure for each model, we then tested stepwise for inclusion of random slopes by subjects and targets for each fixed effect contained in the model, following the same procedure as that described for the fixed effects (Baayen, 2008, 2014; Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). If more than one random slope significantly improved the model fit, we first selected the model with the lowest Akaike Information Criterion (AIC) and then proceeded with testing for inclusion of additional slopes. In the Results section, we report the fixed and random effects structure for the best-fit model computed in each analysis[3].

RESULTS

Overall patterns

Tables 3 and 4 provide mean RTs and accuracy scores for lexical decisions to targets, separately for each set and prime type in the L1 and L2 groups. In terms of the accuracy data, we first noted very high accuracy scores of more than 95% correct responses in the orthographic and semantic sets for all prime types and for both participant groups. We therefore did not perform any further analyses on these accuracy scores. The two morphological sets, on the other hand, yielded slightly reduced accuracy scores in all conditions for the L2 (relative to the L1) participants. Furthermore, the two morphological sets had higher accuracy scores following related primes than unrelated primes. Finally, responses were more accurate with targets in the −R than with targets in the +R set.

To analyze these data statistically, we fitted a binary logistic regression model to the accuracy data from the two morphological sets that included the fixed factors Group (L1, L2), Set (+R, −R), and Prime Type (prefixed, suffixed, unrelated). The best-fit model revealed a significant main effect of Prime Type (prefixed: $b = 0.585$, $SE = 0.122$, $z = 4.804$; suffixed: $b = 0.526$, $SE = 0.121$, $z = 4.334$). These results confirmed that target accuracy was higher for both prefixed and suffixed primes (relative to unrelated primes). In contrast, we did not find a main effect of Group (L1 vs. L2: $b = 0.287$, $SE = 0.298$, $z = 0.962$) or Set ($b = 0.312$, $SE = 0.606$, $z = 0.515$).

Table 3. Mean RTs (standard deviations in parentheses) in milliseconds and percent correct accuracy scores for the L1 group.

Priming	Morphological		Orthographic	Semantic
	−R	+R		
Prime type	Unrelated		Unrelated	Unrelated
RT	625 (133)	631 (138)	582 (118)	600 (118)
Accuracy	93.10%	87.90%	98.30%	98.20%
Prime Type	Suffixed		Word initial	Related
RT	600 (132)	604 (142)	569 (125)	594 (134)
Priming Effect	25	27	13	6
Accuracy	95.80%	92.90%	97.70%	97.20%
Prime type	Prefixed		Word final	
RT	610 (152)	614 (147)	581 (129)	
Priming Effect	15	17	1	
Accuracy	97.90%	90.50%	97.90%	

Table 4. Mean RTs (standard deviations in parentheses) in milliseconds and percent correct accuracy scores for the L2 group.

Priming	Morphological		Orthographic	Semantic
	−R	+R		
Prime type	Unrelated		Unrelated	Unrelated
RT	754 (211)	716 (209)	654 (184)	677 (175)
Accuracy	89.10%	85.90%	97.20%	95.60%
Prime Type	Suffixed		Word initial	Related
RT	732 (232)	689 (214)	648 (202)	677 (162)
Priming Effect	22	27	6	0
Accuracy	90.60%	89.90%	96.90%	95.80%
Prime type	Prefixed		Word final	
RT	716 (210)	699 (233)	640 (166)	
Priming Effect	38	17	14	
Accuracy	91.30%	88.40%	95.70%	

With regard to the RT data, Tables 3 and 4 show overall longer RTs for the L2 than the L1 participants. Secondly, the two morphological sets yielded considerable facilitation in both participant groups (L1, L2) for both prefixed and suffixed words as well as for both lexically restricted and unrestricted affixes (±R). Thirdly, the orthographic and semantic sets yielded small tendencies toward facilitation with some of the prime types, but facilitation from morphological primes was always numerically larger than that from orthographic or semantic primes. To analyze these data statistically, we fitted a number of mixed-effect linear regression models to the RT data.

Morphological priming

Our main analysis tested morphological priming for different types of derived words (prefixed and suffixed, −R and +R) and groups of speakers (L1 and L2). The best-fit model (Table 5) included fixed effects for Group (L1, L2), Set (−R, +R), and Prime Type (suffixed, prefixed, unrelated) and their interactions, as well as the centered covariates Block and Prime Letters, because they both improved the model fit. The effect of Block on RTs was significant (b = −0.049, SE = 0.004, t = −11.800) while the effect of Prime Letters was not (b = 0.011, SE = 0.006, t = 1.682). The model revealed significant main effects of Prime Type for both prefixed and suffixed primes (both $|t|$s > 7.013). In contrast, none of the interactions involving Group, Set, and Prime Type were significant (all $|t|$s < 1.302). By changing the baseline for the factor Prime Type to 'prefixed', we directly compared prefixation to suffixation priming. No significant difference was found (b = −0.011, SE = 0.0072, t = −1.597).

Table 5. Fixed effects for the overall model of the two morphological sets (± R).

Fixed effects	Estimate	*SE*	*t*
(Intercept)	6.4777	0.0256	253.315*
Main effect: Prime Type (suffixed vs. unrelated)	−0.0492	0.0068	−7.261*
Main effect: Prime Type (prefixed vs. unrelated)	−0.0378	0.0054	−7.013*
Group (L1 vs. L2) × Prime Type (suffixed vs. unrelated)	−0.0077	0.0104	−0.739
Group (L1 vs. L2) × Prime Type (prefixed vs. unrelated)	0.0107	0.0107	-1.004
Set (−R vs. +R) × Prime Type (suffixed vs. unrelated)	0.0006	0.0101	0.056
Set (−R vs. +R) × Prime Type (prefixed vs. unrelated)	−0.0114	0.0100	−1.132
Group (L1 vs. L2) × Set (−R vs. +R) × Prime Type (suffixed vs. unrelated)	0.0045	0.0200	0.225
Group (L1 vs. L2) × Set (−R vs. +R) × Prime Type (prefixed vs. unrelated)	0.0260	0.0200	1.302

*Formula in R: log (RT) ~ Group * Set * Prime Type + Block + Prime Letters + (1 + Prime Type + Block + Prime Letters | subject) + (1 + Group + Block | target)*

Note. *$p < .05$.

The results from the above model yielded similar outcomes for prefixed and suffixed words, for both −R and +R forms, and for the two participant groups. However, a lack of a three-way interaction could be due to lack of power and does not necessarily mean that the priming effects for the two morphological types, the two item sets, and the two participant groups were all reliable. To test whether this was the case, we ran four additional linear-mixed effect models separately for each set and group. All models included Prime Type as fixed effect plus the covariate Block, as this significantly improved the model fit. The results from the best-fit models, as well as their formulas, are provided in Table 6, where it can be seen that all morphological priming effects proved to be significant. Furthermore, by back-transforming the estimates from the models into raw RTs, we computed the size of each morphological priming effect as estimated by the statistical models. For L1 speakers, the estimated priming effect for −R items was 26 milliseconds for suffixed primes and 19 milliseconds for prefixed primes; the effect for +R items was 32 milliseconds for suffixed primes and 26 milliseconds for prefixed primes. For the L2 group, −R items showed an estimated priming effect of 26 milliseconds with suffixed primes and 38 milliseconds with prefixed primes; +R items showed an estimated priming effect of 26 milliseconds with suffixed primes and 23 milliseconds with prefixed primes. Overall, our results from the morphological sets indicate significant derivational priming for both prefixed and suffixed words, lexically restricted and unrestricted primes, and for both L1 and L2 speakers[4]. These results are graphically illustrated in Figure 1.

Table 6. Fixed effects for models split by group and set (± R).

Fixed effects	Estimate	*SE*	*t*
L1 Group, −R Set			
(Intercept)	6.3982	0.0263	243.004*
Prime Type (suffixed vs. unrelated)	−0.0442	0.0087	−5.092*
Prime Type (prefixed vs. unrelated)	−0.0321	0.0086	−3.730*
Formula in R: log (RT) ~ Prime Type + Block + (1 + Block | subject) + (1 | target)			
L1 Group, +R Set			
(Intercept)	6.4194	0.0308	208.662*
Prime Type (suffixed vs. unrelated)	−0.0527	0.0159	−3.323*
Prime Type (prefixed vs. unrelated)	−0.0426	0.0150	−2.836*
Formula in R: log (RT) ~ Prime Type + Block + (1 + Block | subject) + (1 + Prime Type | target)			
L2 Group, −R Set			
(Intercept)	6.5797	0.0410	160.570*
Prime Type (suffixed vs. unrelated)	−0.0361	0.0112	−3.225*
Prime Type (prefixed vs. unrelated)	−0.0544	0.0112	−4.859*
Formula in R: log (RT) ~ Prime Type + Block + (1 + Block | subject) + (1 | target)			
L2 Group, +R Set			
(Intercept)	6.5433	0.0441	148.436*
Prime Type (suffixed vs. unrelated)	−0.0382	0.0111	−3.428*
Prime Type (prefixed vs. unrelated)	−0.0330	0.0112	−2.951*
Formula in R: log (RT) ~ Prime Type + Block + (1 | subject) + (1 + Block | target)			

Note. $^{*}p < .05$.

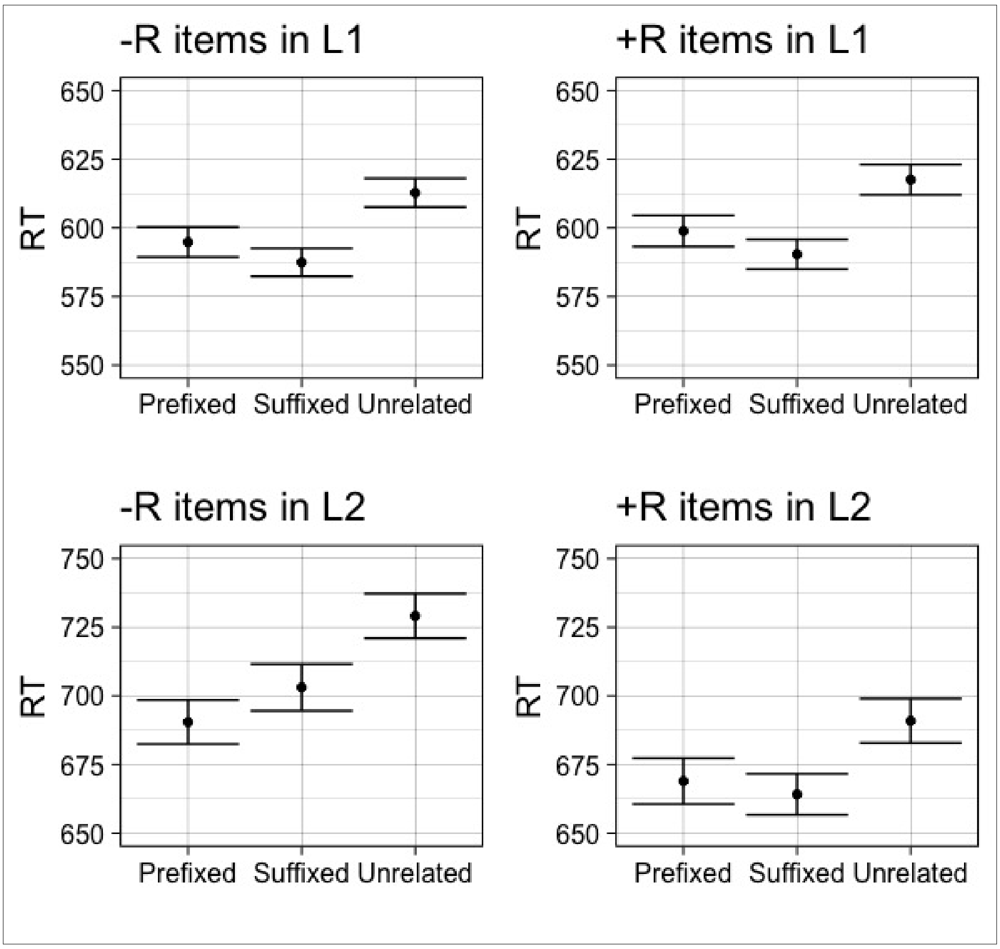

Figure 1. Back-transformed log RTs for the two morphological sets (+R, −R) in the two participant groups (L1, L2).

Additional analyses

The purpose of the additional analyses was to compare the morphological priming effects to the magnitudes of orthographic and semantic priming effects. The results are provided in Table 7. In terms of morphological versus orthographic priming, for this comparison, both prefixed and word-final (orthographic) overlap primes were labeled 'word final', while both suffixed and word-initial (orthographic) overlap primes were labeled 'word initial'. The best-fit model included the fixed factors of Group (L1, L2), Relatedness Type (morphological, orthographic), and Prime Type (word initial, word final, unrelated), their interactions, and the covariates Block and Prime Letters, which both improved model fit and had a significant effect on RTs (Block: $b = -0.049$, $SE = 0.004$, $t = -12.684$; Prime Letters: $b = 0.012$, $SE = 0.005$, $t = 2.212$). As shown in Table 7, the model revealed significant two-way interactions for the two participant groups between Relatedness Type and Prime Type for both word-final and word-initial prime types (both $|t|$s > 3.267), which were due to larger suffixation than word-initial orthographic priming and larger prefixation than word-final orthographic priming. There were no significant three-way interactions between Group, Relatedness Type, and Prime Type or two-way interactions between Group and Prime Type.

Table 7. Fixed effects from the models testing morphological versus orthographic priming and morphological versus semantic priming.

Fixed effects	Estimate	*SE*	*t*
Morphological vs. orthographic priming			
(Intercept)	6.4406	0.0203	317.897*
Prime Type (word initial vs. unrelated)	−0.0344	0.0045	−7.570*
Prime Type (word final vs. unrelated)	−0.0241	0.0042	−5.800*
Group (L1 vs. L2) × Prime Type (word initial vs. unrelated)	−0.0089	0.0084	−1.059
Group (L1 vs. L2) × Prime Type (word final vs. unrelated)	0.0119	0.0083	1.430
Relatedness (morphological vs. orthographic) × Prime Type (word initial vs. unrelated)	−0.0303	0.0090	−3.378*
Relatedness (morphological vs. orthographic) × Prime Type (word final vs. unrelated)	−0.0272	0.0083	−3.267*
Group (L1 vs. L2) × Relatedness (morphological vs. orthographic) × Prime Type (word initial vs. unrelated)	−0.0003	0.0168	0.018
Group (L1 vs. L2) × Relatedness (morphological vs. orthographic) × Prime Type (word final vs. unrelated)	−0.0033	0.0166	−0.202
*Formula in R: log (RT) ~ Group * Relatedness Type * Prime Type + Block + Prime Letters + (1 + Set + Block + Prime Letters | subject) + (1 + Group + Block | target)*			
Suffixation vs. semantic priming			
(Intercept)	6.4426	0.0218	295.265*
Prime Type (related vs. unrelated)	−0.0250	0.0060	−4.199*
Group (L1 vs. L2) × Prime Type (related vs. unrelated)	−0.0095	0.0090	−1.056
Relatedness (morphological vs. semantic) × Prime Type (related vs. unrelated)	−0.0334	0.0119	−2.811*
Group (L1 vs. L2) × Relatedness (morphological vs. semantic) × Prime Type (related vs. unrelated)	0.0026	0.0180	0.144
*Formula in R: log (RT) ~ Group * Relatedness Type * Prime Type + Block + (1 + Relatedness Type + Block | subject) + (1 + Group + Prime Type + Block | target)*			

Table 7. Continued.

Fixed effects	Estimate	*SE*	*t*
Prefixation vs. semantic priming			
(Intercept)	6.4478	0.0220	292.858*
Prime Type (related vs. unrelated)	−0.0233	0.0046	−5.089*
Group (L1 vs. L2) × Prime Type (related vs. unrelated)	−0.0013	0.0092	−0.137
Relatedness (morphological vs. semantic) × Prime Type (related vs. unrelated)	−0.0320	0.0091	−3.502*
Group (L1 vs. L2) × Relatedness (morphological vs. semantic) × Prime Type (related vs. unrelated)	0.0233	0.0183	1.276

*Formula in R: log (RT) ~ Group * Relatedness Type * Prime Type + Block + (1 + Relatedness Type + Block | subject) + (1 + Group + Block |* target)

Note. *$p < .05$.

With regard to morphological versus semantic priming, the semantic set only included two Prime Types (related, unrelated), while the morphological sets contained three Prime Types (prefixed, suffixed, unrelated). We therefore had to perform two separate analyses, one comparing prefixation priming to semantic priming (prefixed/related prime, unrelated prime) and one comparing suffixation priming to semantic priming (suffixed/related prime, unrelated prime). Both models contained the fixed factors Group (L1, L2), Relatedness Type (morphological vs. semantic) and Prime Type (related, unrelated) and their interactions, together with Block, as it improved model fit and had a significant effect on RTs in both models (both $|t|$s > 11). As shown in Table 7, both models yielded significant two-way interactions between Relatedness Type and Prime Type (in both models, $|t|$s > 2.811) due to larger morphological than semantic priming. The three-way interactions with Group (L1, L2) were not significant (in both models, $|t|$s < 1.276). Overall, the additional analyses focusing on the control item sets indicated that the morphological priming effects reported in Tables 5 and 6 for both L1 and L2 speakers and for all the different types of derived words cannot be attributed to orthographic or semantic prime–target overlap.

DISCUSSION

Summary of findings

In the present study, we found significant morphological priming effects for both L1 and L2 speakers of German and for different types of derived words. This finding is in line with results from previous masked priming studies for (suffixed) derived word forms in a variety of languages, including English (Silva & Clahsen, 2008), German (Jacob et al., 2018), Turkish (Kirkici & Clahsen, 2013), and extends them to derivation by prefixation. Furthermore, in line with previous L1 research, morphological priming in both L1 and L2 speakers was clearly dissociable from facilitation due to orthographic or semantic prime–target overlap (Rastle et al., 2000).

Previous (L1) masked priming studies reported significant priming effects for both suffixed and prefixed word forms (Diependaele et al., 2009; Forster & Azuma, 2000; Grainger et al., 1991; Heide et al., 2010; Kim et al., 2015). However, while these earlier results come from different experiments with different target words and different participants, precluding any direct comparisons of priming magnitudes, the current study was specifically designed to measure priming with existing prefixed and suffixed word forms using the same targets and within the same participants. We found significant priming effects with both prefixed and suffixed words. This finding indicates efficient morphological decomposition for both prefixed words and suffixed words, which seems to contradict claims made in the literature that prefixed words might be less susceptible to decomposition than suffixed ones (Beauvillain, 1996; Bergman et al., 1988; Colé et al., 1989; Ferrari Bridgers & Kacinik, 2017). However, all these prior studies have employed experimental techniques in which stimuli were overtly presented for lexical decision, which may explain why these studies yielded different results from the masked priming experiments testing existing prefixed words (Diependaele et al., 2009; Forster & Azuma, 2000; Grainger et al., 1991; Heide et al., 2010; Kim et al., 2015). While masked priming is supposed to tap into early prelexical stages of visual word recognition (Marslen-Wilson, 2007), RTs from overtly presented stimuli also include later processes of lexical retrieval. Hence, these latter techniques are less likely to detect processes of (prelexical) morphological decomposition than masked priming. Another finding from our study is that derived word forms with both lexically restricted and unrestricted affixes yielded significant masked priming effects, replicating previous results from Silva and Clahsen (2008) on *-ness* and *-ity* nominalizations in English and extending them to prefixed words.

Mechanisms of morphological decomposition

The priming effects that we obtained for derived word forms are consistent with different accounts of morphological processing during reading: (a) affix stripping (Rastle & Davis, 2008), (b) morphemic decomposition (Stockall & Marantz, 2006), and (c) edge-aligned embedded word activation (Grainger & Beyersmann, 2017).

Affix stripping, originally proposed by Taft and Forster (1975) and further developed in recent research (Amenta & Crepaldi, 2012; Rastle & Davis, 2008), is conceived of as a general mechanism of visual word recognition that is sensitive to the surface form of a morphologically complex word and is supposed to apply to all kinds of affixed word forms. In our case, affixes are stripped off from word forms such as *unsauber*, *inaktiv*, *Sauberkeit*, and *Aktivität*, by which the prime words' corresponding stems are isolated, thereby facilitating the subsequent recognition of the related target words *sauber* and *aktiv*, respectively. The morphemic decomposition account (e.g., Gwilliams & Marantz, 2018; Stockall & Marantz, 2006) holds that the recognition system exhaustively decomposes all morphologically complex words into their basic morphemes according to the grammatical rules of the language. As the items we tested are fully parsable into their morphemes, the priming effects obtained are consistent with this account. Finally, according to Grainger and Beyersmann's (2017) account, embedded words (rather than affixes or morphemes) represent the primary reading units, with embedded words proposed to be activated at both edges of the letter string. This account applies to derived words such as *unsauber* and *Sauberkeit* with the embedded word sauber, the activation of which may cause a priming effect on the target word sauber.

These three accounts can only partially explain the experimental findings from the current morphological processing literature, especially if we include evidence from both L1 and L2 speakers and if we consider different types of morphologically complex words. What matters for affix stripping, morphemic decomposition, and embedded word activation is the presence of segmentable affixes/morphemes/words, irrespective of whether the complex word is the result of derivation, compounding, or inflection. However, several studies have revealed some degree of variability as to how these supposedly ubiquitous mechanisms apply, particularly for inflection.

It is true that compounds have yielded robust and stable priming effects across different morphological types and speaker groups in a number of previous studies, similar to what we found for derived word forms. Masked priming studies, for example, revealed efficient priming effects for both the head and the modifier components of compounds, and for both transparent and opaque compounds (Beyersmann et al., 2018; Duñabeitia, Laka, Perea, & Carreiras, 2009; Fiorentino & Fund-Reznicek, 2009). Furthermore, studies comparing L1 and proficient L2 speakers found similar effects of decomposition of compounds for both speaker groups (González Alonso, Baquero Castellanos, &

Müller, 2016; M. Li et al., 2017; Uygun & Gürel, 2017). Priming studies of inflection, on the other hand, have led to more variable outcomes. For L1 speakers, morphological priming effects indicative of stem–affix decomposition were found to be reduced for irregular (relative to regular) inflected words, even for irregular forms that have segmentable affixes/morphemes (Jacob, Fleischhauer, & Clahsen, 2013; Neubauer & Clahsen, 2009; Sonnenstuhl, Eisenbeiss, & Clahsen, 1999). For L2 speakers, a number of masked priming studies that directly compared derivation and inflection (Jacob et al., 2018; Kirkici & Clahsen, 2013; Silva & Clahsen, 2008) found efficient priming effects for derivation, but reduced or no priming for regular inflection in the same speakers. In contrast, other L2 studies reported significant priming effects for inflected words (Feldman et al., 2010; Foote, 2017). Models of morphological processing should be able to capture both the consistency and variability of the decomposition mechanism for different linguistic morphological types and speaker groups. In the following, we offer a few (admittedly speculative) thoughts of how this could be achieved.

From a linguistic perspective, derivation and compounding have much in common. Both are word formation processes as opposed to inflectional or paradigmatic processes (for a review, see Spencer, 1991). Item-and-arrangement accounts of morphology (Lieber, 1992; Selkirk, 1986) particularly stress the similarities between compounding and derivation, in that the difference between compounding and derivation is supposed to reduce to one property, namely, that derivational morphemes are subcategorized as only appearing in combination with a stem. Apart from that, the component parts of compounds and derived words are lexical items with their own form and meaning properties. Unlike word formation processes, inflectional processes do not yield any new lexical entries, but are instead feature–form mappings that specify the form that realizes or spells out a particular set of features. An inflected word form such as *builds*, for example, is the result of an inflectional rule that spells out the morphosyntactic feature set (3rd person, singular, present, indicative) by adding the exponent /s/ to the base verb 'build' (Anderson, 1992; Matthews, 1991; Stump, 2001).

These linguistic considerations help to better understand the priming results. Suppose a principle of full decomposition, according to which recognition and lexical access are facilitated when the whole letter string can be completely divided into its basic lexemes. Grainger and Beyersmann (2017) originally posited this principle for embedded words to explain why compounds such as *teacup* and *honeymoon* effectively prime their respective base words, whereas this is not the case for words such as *window* or *carpet* for which full decomposition fails. We suggest to extend the principle of full decomposition to embedded lexemes. Assuming that derivational morphemes are indeed lexemes (Lieber, 1992), full decomposition then applies to both compounds and derived words and provides a boost in activation to the embedded component parts, which explains why compounds such as teacup and honeymoon and derived words such as *unsauber* and *Sauberkeit* yield priming effects for both L1 and L2 speakers.

For inflected word forms, on the other hand, lexeme-based decomposition only yields a partial analysis of the corresponding letter string, given that forms such as builds contain exponents of grammatical feature sets rather than lexemes. Instead, inflected words additionally invoke grammatical processes/rules for mapping exponents to morphosyntactic feature sets. If these rules are fully operative, they ensure complete decomposition of inflected words and, consequently, efficient priming. There are, however, circumstances that may reduce the functionality of these rules. One case is irregular inflection, that is, exceptions that do not support the general rule and in which additional processes (e.g., phonological readjustments) are required to map the exponent to its corresponding morphosyntactic feature set. As mentioned above, reduced priming effects have been reported in such cases relative to inflected forms that fully support the general rule. Another factor that modulates inflectional priming is whether a particular language represents an individual's L1 or L2. As mentioned above, reduced or no priming for regular inflection was found in L2 (unlike in L1 speakers[5]).

These considerations suggest that morphological decomposition during visual word recognition is not just driven by the surface form of complex words (affix stripping), but that morphological processing is also sensitive to the linguistic distinction between word formation (derivation, compounding) on the one hand and inflectional processes on the other, contrary to the view that «no characterization of the inflection versus derivation split has proved relevant» (Marantz, 2016, p. 157). We do, however, concede that more experimental work is needed that directly compares derivation/compounding versus inflection regarding morphological processing to further validate the proposed distinction.

Conclusion

In the current study, we obtained significant masked priming effects for different kinds of derived word forms (prefixed and suffixed, lexically restricted and lexically unrestricted) and different groups of speakers (L1, L2). Furthermore, these priming effects were dissociable from both orthographic and semantic prime–target relatedness, suggesting that they are genuinely morphological in nature. Our findings contrast with previous studies reporting more variability for inflectional priming. We attribute the differences between derivational and inflectional priming to the linguistic contrast between derivation and inflection, which permits direct lexeme-based decomposition for derived words but not for inflected word forms. Although the results from the present study, along with the reviewed results from previous priming experiments, confirm this conjecture, the evidence for a split between derivation/compounding versus inflection with respect to morphological decomposition is still scarce and needs to be ascertained through further studies.

NOTES

1. As explained by Sassenhagen and Alday (2016), performing inferential statistics such as *t* tests to verify the matching of items in different conditions is problematic for the following reasons. First, we would be making inferences about the specific items selected, which a *t* test (or the like) does not allow to make. Second, a nonsignificant result in a *t* test should not be taken as evidence for the absence of a difference.
2. Three of the original 12 prime–target pairs from the semantic set had to be recoded as fillers due to experimental error, leaving 18 prime–target pairs in each list, 9 per prime type in this set. The three removed items are not included in the description of the item characteristics.
3. The tables showing model outputs are meant to present as clearly as possible the results from our main experimental manipulation, namely, priming effects. Therefore, we only included the lines from the model outputs that contain the fixed effect for Prime Type; effects from other predictors, if relevant, are reported in the text.
4. Following the suggestion of one anonymous reviewer, we additionally examined whether Transition Probability (TP) interacts with the morphological priming effects we report. TP is normally defined as the conditional probability of encountering the whole complex word given its stem, and it is computed by dividing the word form frequency of the complex word by the sum of the frequencies of all words sharing the same stem (Hay, 2001; Lehtonen, Monahan, & Poeppel, 2011; Solomyak & Marantz, 2010). For prefixed words, the relevant transition may be from the prefix rather than from the stem; therefore, we also computed TP from

prefix by dividing the word form frequency of the prefixed word by its prefix frequency. Because TP is a property of the morphologically related prime, but not of the unrelated prime, we used the same TP for the prefixed and unrelated prime in one analysis testing TP effects on prefixation priming. TP effects on suffixation priming were determined similarly in a separate analysis. Linear mixed-effect models were fitted to log RTs with the fixed effects Group (L1, L2) and Prime Type (prefixed/suffixed, unrelated) and their interaction. The (centered) continuous predictor TP (or TP from prefix, respectively), as interacting with Prime Type, was tested for inclusion. We found that these predictors did not improve model fit, which suggests no effect of TP on the morphological priming effects. However, because our study was not specifically designed to test TP effects, the range of TPs was very limited and substantially varied between prefixed and suffixed words. Hence, whether TP affects prefixation and suffixation priming to different degrees remains a question worth investigating in future research.

5. Two recent large-scale priming studies have identified the source of the L1/L2 difference in inflectional priming (Bosch, Veríssimo, & Clahsen, 2019; Veríssimo, Heyer, Jacob, & Clahsen, 2018), namely, age of acquisition (AoA). The first study, examining a group of 93 Turkish–German bilinguals, revealed that the AoA of the L2 (German) had a pronounced effect on inflectional priming (but not on derivational priming), with nativelike priming if acquisition started before the ages of 5–6 and with gradually declining inflectional priming effects for later ages of acquisition. The second study (Bosch et al., 2019) also showed striking AoA effects on inflectional priming. These findings have been attributed to how and when inflectional rules are learned, specifically to a sensitive period for paradigm-based learning mechanisms during which inflectional rules can be efficiently extracted from the input. A long-term consequence of early acquisition of inflectional

paradigms is robust morphological priming from inflected forms. By contrast, later AoAs (i.e., those outside the sensitive period) yield weaker paradigmatic representations and as a result lead to the AoA-related gradual decline in morphological priming from inflected forms that was found in the above-mentioned studies (for further discussion, see Veríssimo et al., 2018).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website: Appendix S1. Experimental Items and Their Characteristics.

Appendix

A complete list of experimental materials and fillers, together with their characteristics, can be found at the article's DOI: https://doi.org/10.1111/lang.12370. For consistency with the other three publications, I report here a list of the items contained in the morphological, orthographic, and semantic item sets, together with their English translations.

Morphological -R set

Prefixed Prime		Suffixed Prime		Unrelated Prime		Target	
unförmlich	'informal'	Förmlichkeit	'formality'	maskulin	'masculine'	förmlich	'formal'
unselig	'unfortunate'	Seligkeit	'blessedness'	abartig	'abnormal'	selig	'blessed'
ungiftig	'non-toxic'	Giftigkeit	'toxicity'	authentisch	'authentic'	giftig	'toxic'
ungesellig	'unsociable'	Geselligkeit	'sociability'	akzeptabel	'acceptable'	gesellig	'sociable'
ungastlich	'inhospitable'	Gastlichkeit	'hospitality'	konklusiv	'conclusive'	gastlich	'hospitable'
unritterlich	'unchivalrous'	Ritterlichkeit	'chivalry'	emotionell	'emotional'	ritterlich	'chivalrous'
unsauber	'unclean'	Sauberkeit	'cleanliness'	Kriterium	'criterion'	sauber	'clean'
unsportlich	'unsporting, unathletic'	Sportlichkeit	'sportiness'	Referendum	'referendum'	sportlich	'sporty'
unhöflich	'not polite'	Höflichkeit	'courtesy'	Konversion	'conversion'	höflich	'polite'
untrennbar	'inseparable'	Trennbarkeit	'separability'	Ventilator	'ventilator'	trennbar	'separable'
unsterblich	'immortal'	Sterblichkeit	'mortality'	Analphabet	'illiterate'	sterblich	'mortal'
unpünktlich	'unpunctual'	Pünktlichkeit	'punctuality'	Geschwister	'siblings'	pünktlich	'punctual'

Morphological +R set

Prefixed Prime		Suffixed Prime		Unrelated Prime		Target	
inaktiv	'inactive'	Aktivität	'activity'	arbiträr	'arbitrary'	aktiv	'active'
ineffektiv	'ineffective'	Effektivität	'effectiveness'	kumulativ	'cumulative'	effektiv	'effective'
infertil	'infertile'	Fertilität	'fertility'	provokant	'provocative'	fertil	'fertile'
inhomogen	'inhomogeneous'	Homogenität	'homogeneity'	spirituell	'spiritually'	homogen	'homogeneous'
inhuman	'inhuman'	Humanität	'humanity'	horizontal	'horizontal'	human	'human'
inopportun	'inopportune'	Opportunität	'opportunity'	manuell	'manual'	opportun	'opportune'
instabil	'unstable'	Stabilität	'stability'	Demonstration	'demonstration'	stabil	'stable'
inoffensiv	'unoffensive'	Offensivität	'offensiveness'	Medikament	'medicine'	offensiv	'offensive'
inflexibel	'inflexible'	Flexibilität	'flexibility'	Aristokratie	'aristocracy'	flexibel	'flexible'
inkompatibel	'incompatible'	Kompatibilität	'compatibility'	Evolution	'evolution'	kompatibel	'compatible'
insensibel	'insensitive'	Sensibilität	'sensitivity'	Marmelade	'marmalade'	sensibel	'sensitive'
invariabel	'invariable'	Variabilität	'variability'	Population	'population'	variabel	'variable'

Orthographic set

Final Overlap Prime		Initial Overlap Prime		Unrelated Prime		Target	
Karaffe	'carafe'	Affekt	'emotion'	Kontext	'context'	Affe	'monkey'
Kompass	'compass'	Passion	'passion'	Etikett	'label'	Pass	'pass, passport'
Limbus	'limbo'	Busch	'bush'	Minze	'mint'	Bus	'bus'
abstrakt	'abstract'	Traktor	'tractor'	winzig	'tiny'	Trakt	'section'
Anagramm	'anagram'	Grammatik	'grammar'	Prestige	'prestige'	Gramm	'gram'
Mammut	'mammoth'	Mutation	'mutation'	Pulver	'powder'	Mut	'courage'
Sonett	'sonnet'	netto	'net'	präzis	'precise'	nett	'kind'
mental	'mental'	Talent	'talent'	Komet	'comet'	Tal	'valley'
Protest	'protest'	Testament	'testament'	Phantasie	'fantasy'	Test	'test'
Tutor	'tutor'	Tortur	'torture'	Dattel	'date'	Tor	'gate'
Alarm	'alarm'	Armee	'army'	Liter	'liter'	arm	'poor'
Plissee	'pleats'	Seele	'soul'	Praline	'praline'	See	'lake'

Semantic Set

Related Prime		Unrelated Prime		Target	
Kaktus	'cactus'	Brett	'board'	Wüste	'desert'
Pfanne	'pan'	Apostroph	'apostrophe'	Herd	'stove'
bankrott	'bankrupt'	visuell	'visual'	pleite	'broke'
faul	'lazy'	taub	'deaf'	fleißig	'diligent'
extrem	'extreme'	düster	'gloomy'	mild	'mild'
Konsonant	'consonant'	Gewürz	'spice'	Vokal	'vocal'
lokal	'local'	explizit	'explicit'	global	'global'
Laie	'layman'	Fliege	'fly'	Experte	'expert'
Durst	'thirst'	Frisur	'hairstyle'	Hunger	'hunger'

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Morphological decomposition in Bantu: A masked priming study on Setswana prefixation

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ABSTRACT

African languages have rarely been the subject of psycholinguistic experimentation. The current study employs a masked visual priming experiment to investigate morphological processing in a Bantu language, Setswana. Our study takes advantage of the rich system of prefixes in Bantu languages, which offers the opportunity of testing morphological priming effects from prefixed inflected words and directly comparing them to priming effects from prefixed derived words on the same targets. We found significant priming effects of similar magnitude for both prefixed inflected and derived word forms, which were clearly dissociable from prime-target relatedness in both meaning and (orthographic) form. These findings provide support for a (possibly universal) mechanism of morphological decomposition applied during early visual word recognition that segments both (prefixed) inflected and derived word forms into their morphological constituents.

Keywords: prefixes; inflection; affix stripping; visual word recognition; African languages

INTRODUCTION

In recent years, experimental psycholinguistics has substantially gone beyond its traditional focus on English by including a wider range of languages as well as cross-linguistic comparisons between different languages into its research agenda; for recent reviews, see, for example, Norcliffe, Harris, and Jaeger (2015) and Clahsen (2016). Nevertheless, there is – apart from a few exceptions (e.g. Kgolo & Eisenbeiss, 2015; Saah & Goodluck, 1995) – still very little experimental research on African languages. The current study contributes to closing this gap, by presenting new findings on morphological processing in Setswana, a Bantu language widely spoken in southern Africa.

There are a number of ways in which research on language processing may benefit from cross-linguistic comparisons and from considering a wider range of languages more generally. Such evidence may, for example, help to determine to what extent representations and mechanisms for language processing are universal and to what extent they are shaped by particular properties of individual languages. Cross-linguistic research may also contribute to adjudicate between different models of language processing, through investigating linguistic phenomena that are not available from more commonly studied languages.

Our case study for the current paper concerns *morphological decomposition*, a supposedly universal mechanism according to which both prefixed and suffixed word forms – irrespective of whether they are resulting from derivational or inflectional processes – are segmented into their morphological component parts ('morphemes') during word recognition; see Marslen-Wilson (2007) for a review. Morphological decomposition has been claimed to function automatically and subconsciously prior to lexical access, operating on complex and pseudo-complex words, both existing and non-words, so that, for example, *corner* is temporarily segmented into [corn-er] or *quickify* into [quick-ify]; see, for example, Beyersmann, Casalis, Ziegler, and Grainger (2015), Beyersmann, Cavalli, Casalis, and Colé (2016), Rastle, Davis, and New (2004), Rastle, Davis, Marslen-Wilson, and Tyler (2000).

The most commonly used experimental technique to examine morphological decomposition in language processing is masked visual priming (Forster, 1998). In a typical masked priming experiment, a series of target words are presented on a computer screen and participants have to indicate, via a button press, whether each target is an existing word or not (i.e. they perform a lexical decision task). Each target word is preceded by a visual mask followed by the so-called 'prime' word, which is presented very briefly (between 30 and 70 milliseconds) in order to preclude or at least reduce conscious recognition. In morphological priming studies, the critical target words are preceded by a morphologically related prime (e.g. *player* → *play*) or by an (otherwise matched) unrelated prime (e.g. *farmer* → *play*). Lexical decision times on targets following morphologically related primes tend to be faster than those following unrelated primes. This facilitatory effect is attributed to morphological decomposition (e.g. [play-er]), which is then supposed to speed up the recognition of a related target word (viz. *play*), in essence a stem-repetition effect as a result of the decomposed prime word. This is referred to as 'morphological priming', in contrast to facilitatory effects resulting from pure orthographic overlap ('orthographic priming') or pure semantic relatedness ('semantic priming').

There are three prominent theoretical accounts for masked morphological priming effects during reading: (i) affix stripping (e.g. Rastle & Davis, 2008), (ii) single-route full decomposition (e.g. Stockall & Marantz, 2006), and (iii) edge-aligned embedded word activation (e.g. Grainger & Beyersmann, 2017). According to the mechanism of *affix stripping*, both derivational and inflectional prefixes and suffixes are segmented from their stems during visual word recognition, yielding priming effects for morphologically related words. According to the *single-route full decomposition* account, the language processing system exhaustively decomposes all morphologically complex words into their basic morphemes using a given language's grammatical rules. This mechanism applies irrespective of the presence of overt affixation, such as in the case of *sang*, which may be decomposed into the stem sing plus an abstract past-tense morpheme. The third account, *edge-aligned embedded word activation*, holds that the processor activates embedded words or stems at both edges of a given letter string, effectively segmenting a morphologically complex word's stem from its affixes, but also extracting any embedded stems from words that are not morphologically complex (such as *cash* in *cashew*).

However, none of these three major approaches has tried to account for how language-specific properties may influence morphological decomposition. On the one hand, reliable priming effects for morphologically complex words have been reported for different languages and for different types of morphological phenomena. For English, there is a rich body of masked priming experiments testing derived word forms (e.g. Rastle et al., 2000; Silva & Clahsen, 2008), inflected word forms (e.g. Crepaldi, Rastle, Coltheart, & Nickels, 2010; Kielar, Joanisse, & Hare, 2008; Silva & Clahsen, 2008), and compounds (Fiorentino & Fund-Reznicek, 2009). Similarly, a number of masked priming studies have investigated morphological phenomena in other Indo-European languages such as German (derivation: Mousikou & Schroeder, 2019; inflection: Neubauer & Clahsen, 2009), Dutch (Diependaele, Sandra, & Grainger, 2009), French (derivation: Giraudo & Grainger, 2000; inflection: Meunier & Marslen-Wilson, 2004), Spanish (Domínguez, Cuetos, & Segui, 2000; Domínguez, Segui, & Cuetos, 2002), and Russian (Kazanina, Dukova- Zheleva, Geber, Kharlamov, & Tonciulescu, 2008). Lastly, there are also some masked priming studies investigating morphological decomposition in non-Indo-European languages, such as Basque (Duñabeitia, Laka, Perea, & Carreiras, 2009), Japanese (Clahsen & Ikemoto, 2012; Fiorentino, Naito-Billen, & Minai, 2016), Korean (Kim, Wang, & Taft, 2015), and Turkish (Kirkici & Clahsen, 2013).

On the other hand, although morphological decomposition is supposed to apply to all kinds of languages and all types of morphologically complex words, properties of individual languages have been shown to modulate the way this mechanism functions. Language processing in Semitic languages such as Arabic and Hebrew, for example, has been argued to be more 'morphological' in nature than in English and other Indo-European languages, in that it seeks to extract a complex word's root and word pattern structure irrespective of its meaning or surface form (Boudelaa & Marslen-Wilson, 2005, 2011); but see Farhy, Veríssimo, and Clahsen (2017). For Japanese, Nakano, Ikemoto, Jacob, and Clahsen (2016) showed that morphological decomposition during reading is modulated by its specific orthography, in this case by the subliminal activation of kanji logograms shared between prime and target. Another case comes from Aronoff, Berg, and Heyer (2016) who suggested that orthographic information may be more salient for English morphological processing than in other languages, because the English spelling system provides direct cues to a word's morphological structure (consider, for example, the past tense morpheme {-ed} which is consistently spelled as <(e)d> despite being differently realised as /t/, /d/, or /əd/).

While research on morphological processing has long recognised the benefits of linguistic diversity and cross-linguistic comparisons, many languages have been left out of previous experimental research, begging the question of whether supposedly general processing mechanisms (e.g. morphological decomposition) are indeed universally applied to different languages and different morphological phenomena. In our present contribution, we take advantage of a particular property of Setswana (and Bantu morphology more generally), namely its rich system of inflectional prefixes. According to current morphological processing accounts, prefixed inflected word forms should be decomposed under masked priming conditions, be it through affix stripping, single-route full decomposition, or embedded word/stem activation, yielding reliable priming effects. Yet, previous masked priming studies have only examined *suffixed* inflected words and prefixed word forms only for derivation. In this respect, current theoretical models are underdetermined by the evidence available, as we simply do not know whether prefixed inflected words exhibit significant priming effects in the same way as prefixed derived words. Indeed, there are reasons to believe that morphological decomposition may work less robustly with prefixed inflected words than with prefixed derived words. As we will lay out in the literature review below, morphological decomposition from inflected words is more affected by item-level properties (regular vs. irregular inflection) and by speaker-level factors ('language status') than decomposition from derived words or compounds. For instance, reduced inflectional priming effects have been reported for bilingual speakers' weaker, late-learned, second language (L2) than their native language (L1). Although Setswana is our participants' L1, Setswana speakers only have limited access to written Setswana, whose use is subordinate to English. Hence the weaker language status of written Setswana may possibly reduce inflectional priming effects during reading for our participants, similarly to what has been found for late bilinguals. The current study examines masked priming effects with prefixed inflected words of Setswana and additionally checks whether priming effects with prefixed inflected and derived words are of similar magnitude, as predicted by all major morphological processing accounts.

LINGUISTIC BACKGROUND: SETSWANA

Setswana, also known as Tswana, is a Bantu language mostly spoken in Botswana, where it is the national language. Setswana is additionally spoken in South-Africa (where it is one of the official languages), Zimbabwe, and Namibia. In Botswana, where the data for the current study were collected, speakers of Setswana vary between 70% and 90% of the population (Andersson & Janson, 1997; Bagwasi, 2003), most of whom speak it as their mother tongue. In Botswana, primary education is offered in Setswana only in the first grade, after which education takes place in English, except for Setswana language classes, which are compulsory until the last year of high school. Despite this limited use of Setswana in the education system, Setswana is the dominant language of Botswana in terms of day-to-day usage. Setswana is not only spoken at home, but is also used in spoken and written form in government offices, local businesses, traditional courts, and even for official deliberations, which are later translated into English (Bagwasi, 2003). Setswana is also widely used in the media, except for the printed media, which are overwhelmingly in English, with some newspapers containing daily inserts in Setswana (Kgolo, 2014).

Written Setswana is based on the Latin alphabet. Like other Bantu languages, Setswana has a rich agglutinative morphology. Prefixes and suffixes can be used to create both inflected and derived words, although there are differences in how this works for the different grammatical classes. One peculiarity of Setswana morphology, and of Bantu languages in general, is the system of noun classes. Setswana comprises 18 different noun classes. All Setswana nouns belong to one of these classes, each of which has distinctive semantic features (for example 'animate' or 'abstract') and/or grammatical features (e.g. singular/plural). These features are encoded by prefixes, which means that each noun class is marked by a distinctive prefix (except for classes 1a and 9, which do not carry a prefix, at least not a common one). Stems can generally be combined with several different prefixes, and the prefix determines the class of the resulting prefixed noun (e.g. *dimo* 'giant' class 1a → *modimo* [mo-dimo] 'god' class 1, *ledimo* [le- dimo] 'storm, hurricane' class 5, *sedimo* [se-dimo] 'spiritual being' class 7). Some of the prefixes are derivational, in that the resulting prefixed nouns have a meaning that is more specific than that of the nominal stem, though related to it. Others are purely inflectional, as they encode, for example, a noun's plural form. Noun prefixes also play a crucial role in Setswana's morpho-syntax, as they govern both noun-phrase internal agreement and subject-verb agreement (Creissels, 2006; Demuth, 2000). For instance, in noun phrases, determiners are selected based on a noun's class, while adjectives are marked by a prefix that agrees with the noun class. Subject-verb agreement in Setswana is marked by so-called 'subject concords', i.e. clitics that are written disjunctively from the verb and that must agree with the subject noun. Furthermore, all agreement elements depend on the noun's prefix (Creissels, 2006; Letsholo & Matlhaku, 2014; Taljard & Bosch, 2006; de Velde, Bostoen, Nurse, & Philippson, 2018). This is illustrated in (1) below where the noun *setlhako* 'shoe' contains the class-7 prefix *se*-, which determines agreement with the adjective *sentsho* 'black', the determiner *se* 'the', and the subject clitic *se*.

(1) Setlhako se sentsho se kgagogile.
Se-tlhako se se-ntsho se kgagog-ile.
NCP7-shoe DET7 AGR7-black SC7 tear-PST
'The black shoe is torn.'
Gloss: NCP = noun class prefix, DET = determiner, AGR = agreement,
SC = subject clitic, PST = past.

Despite the prominent role of prefixes in Bantu languages, there is only one psycholinguistic study that has investigated the processing of prefixed words in these languages. This is the study on Setswana by Kgolo and Eisenbeiss (2015) on prefixed derived nouns. The authors found priming effects with class-1 prefixed nominalizations (e.g. *moreki-REKA* 'buyer-BUY'), which bear a transparent relationship to their stems, both orthographically (the prefix is easily identifiable) and semantically (they always have a clear [+agent] interpretation), as well as for class-9 nominalizations (*theko-REKA* 'a manner of buying-BUY'), which are less transparent, both orthographically (they have no clearly identifiable prefix) and semantically (there is no consistency in how the meaning of the nominalization relates to the meaning of the stem).

Previous research on inflectional priming and prefixation

The present study focuses on prefixed inflected words. In prefixed words, the stem is preceded by an affix (e.g. *prepay*), unlike suffixed words, in which the stem occupies the initial portion of the word, followed by an affix (e.g. *payer*). Across the world's languages, prefixation is less widespread than suffixation (Greenberg, 1963). Affixes can be either derivational or inflectional, the difference being the type of information that they add to the stem. Inflection spells out the grammatical properties of a word (e.g. the form *plays* of the verb to *play*), resulting in a different word form of the same lexeme. In contrast, derivation results in a new lexeme (e.g. the noun *player* from the verb to *play*), which has a different meaning from its stem and often a different grammatical class (Anderson, 1992).

A number of previous masked priming studies have tested priming effects for inflected words, albeit only for suffixed words. These studies have consistently reported significant priming effects for adult native speakers in a number of typologically different languages (e.g. Feldman, Kostić, Basnight-Brown, Đurđević, & Pastizzo, 2010; Kielar et al., 2008; Kirkici & Clahsen, 2013; Pastizzo & Feldman, 2002). Nevertheless, the language status of the speaker groups has been found to modulate the efficacy of morphological decomposition of inflected words: a number of studies have revealed that inflected words yield priming effects with native speakers, but not with non-native late bilinguals. Instead, derived words show masked priming effects in both groups. This L1/L2 contrast with respect to inflectional vs. derivational priming has been obtained for different target languages (e.g. German: Jacob, Heyer, & Veríssimo, 2018; Turkish: Kirkici & Clahsen, 2013; English: Silva & Clahsen, 2008) and has been taken to indicate L2-specific difficulties with the processing of regular inflection in late bilinguals; see Veríssimo, Heyer, Jacob, and Clahsen (2018) for discussion. Furthermore, the efficacy of morphological decomposition with inflected words is affected by the type of inflection, in that smaller masked priming effects have been found for irregular than for regular inflection even amongst L1 speakers (e.g. Pastizzo & Feldman, 2002), and in cases in which both form types are equally decomposable into stems and affixes; see Neubauer and Clahsen (2009) for inflected German participles. By contrast, derivational and compound priming seem to be more robust and stable across different groups of speakers (L1 and L2) and types of items; see e.g. González Alonso, Baquero Castellanos, and Müller (2016), M. Li, Jiang, and Gor (2017), Uygun and Gürel (2017), Duñabeitia et al. (2009), Fiorentino and Fund-Reznicek (2009) for compounds, and Diependaele, Duñabeitia, Morris, and Keuleers (2011), J. Li, Taft, and Xu (2017), Silva and Clahsen (2008) and Ciaccio and Clahsen (2020) for derivation. Taken together, these findings suggest that inflectional priming is less robust across different speaker groups and item types than priming with derived and compound words.

Masked priming experiments for prefixed words are, to our knowledge, only available for derived word forms, and these have revealed significant priming effects for different languages (Diependaele et al., 2009; Forster & Azuma, 2000; Grainger, Colé, & Segui, 1991; Heide, Lorenz, Meinunger, & Burchert, 2010; Kgolo & Eisenbeiss, 2015; Kim et al., 2015). However, at least one study (Kim et al., 2015) reports no priming with prefixed pseudo-words, which has been explained in terms of post-lexical decomposition of prefixed words, in contrast to suffixed words, which are supposed to be decomposed before lexical access. Furthermore, studies using other experimental techniques, such as unprimed lexical decision or eye-movement monitoring, have indicated additional processing costs for prefixed (relative to suffixed) words. The eye-tracking study by Beauvillain (1996) found an effect of cumulative root frequency on first fixation durations for suffixed words, but only on second fixation durations for prefixed words, which is indicative of later access to morphological information. Similarly, Colé, Beauvillain, and Segui (1989), in a lexical decision task, found a cumulative root frequency effect on reaction times (RTs) to suffixed words, but not on RTs to prefixed words. Furthermore, Bergman, Hudson, and Eling (1988) found equal RTs for suffixed and pseudo-suffixed words, but longer RTs for pseudo- prefixed compared to prefixed words, which may suggest that stem extraction is not automatic or not as efficient in prefixed words as compared to suffixed words (but see Taft, 1981 for a different interpretation). Finally, Ferrari Bridgers and Kacinik (2017) report longer RTs in a lexical decision task to prefixed words than suffixed words, which they interpret in terms of larger processing costs for the former relative to the latter. All these findings are in line with the claim (Cutler, Hawkins, & Gilligan, 1985) that the cross-linguistic preference for suffixation over prefixation (Greenberg, 1963) is due to larger processing costs for prefixed words, in which the most important component of a complex word (i.e. the stem) does not occur in the most salient word position (i.e. word-initially).

THE PRESENT STUDY

To contribute new research to the cross-linguistic study of morphological processing, our study on Setswana focuses on testing morphological priming from prefixed inflected words, which was then compared – on the same targets – to priming from prefixed derived words. We additionally investigated potential priming effects with suffixed words as primes to determine whether any priming effects obtained for prefixed words generalise to suffixed words. Finally, because the critical prefixed inflected and derived prime words were not only morphologically related to their target words but were also similar in form and meaning, an *orthographic* and a *semantic* control set were added, the former with prime-target pairs that orthographically overlapped without being morphologically or semantically related, and the latter with prime-target pairs that overlapped in meaning but not in orthographic, phonological, or morphological form.

In the critical item set testing priming with prefixed words, we expected to find reliable priming effects for *derived* words, replicating previous results of masked priming experiments across different languages, including Setswana (Kgolo & Eisenbeiss, 2015). As regards priming effects for prefixed *inflected* words, we considered two conceivable outcomes. One possibility would be that prefixed inflected words exhibit reliable priming effects, similar in magnitude to those from prefixed derived words, in line with what can be expected from the three above-mentioned theoretical accounts ('affix stripping', 'single-route full decomposition', 'edge-aligned embedded word activation'). If we additionally do not find any facilitation from orthographic or semantic relatedness, we would take prefixation priming to be genuinely morphological in nature, resulting from efficient decomposition of both prefixed inflected and prefixed derived words into their component parts. Alternatively, the subordinate status of written Setswana for our speakers may constrain the efficacy of morphological decomposition of inflected words, which, in addition to a possibly larger processing cost related to the word-final position of the stem, would cause no or reduced priming for prefixed inflected words. This would be in line with previous reports of more variability and less robust and stable morphological priming effects for inflectional priming.

As regards suffixation priming, we expected to replicate findings from previous studies that have tested inflectional and derivational priming on the same targets in native speakers, i.e. significant priming effects with both types of primes (e.g. Jacob et al., 2018). However, the language status of written Setswana may also affect priming from suffixed inflected words, possibly yielding reduced or no priming effects for our speakers in such cases, as shown by previous studies on late bilinguals (Kirkici & Clahsen, 2013; Silva & Clahsen, 2008).

Method

Participants

Eighty-five participants (48 women, 36 men, 1 NA) with a mean age of 22.3 years (SD 3.7, range 17–35) took part in the experiment. They were all students at the University of Botswana in Gaborone, Botswana. All of them had high-school level education, 23 of whom already held a university degree and 7 a vocational training certificate. All participants were native speakers of Setswana. Furthermore, they all acquired English during childhood (mean age of acquisition of English: 5.5, SD 1.9, range 0–10) and had intermediate to advanced-level English proficiency, as required for admission at the University of Botswana. Thirteen subjects additionally spoke another African language (five of them from birth) while three additionally spoke French and one spoke Mandarin, all of which were late-learned foreign languages (age of acquisition > 13). All participants indicated being exposed to written Setswana in their daily life to some extent, albeit with a large degree of variability in their use of written Setswana as compared to other languages (mean 31.2%, SD 22.8, range 1–100%). Sixty-two participants indicated reading and writing in English more often than in Setswana, 14 subjects more often in Setswana than in English, and nine participants stated using both languages to the same extent for reading and writing.

Materials

The critical set of items contained prefixed inflected words and prefixed derived words that were tested for potential priming effects *on the same targets*. The design included an additional set testing morphological priming effects with suffixed words, as well as two sets of control items testing for potential orthographic and semantic priming effects. All sets contained related primes, unrelated primes, and identity primes. Identity primes were included to test for repetition priming as a 'sanity check' to ensure that our participants were indeed processing the (masked) primes presented in our experiment. A complete list of the stimuli is provided in the Appendix.

The critical set ('prefixation set') included 28 nouns as targets and prefixed words as primes. The targets were preceded either by an identical prime, by an inflected prime, by a derived prime, or by an unrelated prime. All target nouns belonged to class 9, which is the class with the largest number of members (Otlogetswe, 2012). The prefixed *inflected* prime words were plural forms, which are formed by adding the prefix *di-* to the noun. The plural forms of class-9 nouns belong to class 10. Note that marking the plural in Setswana always causes a change in class. The prefixed *derived* prime words were class-14 nouns, i.e. forms derived by adding the prefix *bo-*, which is productively used to transform a noun into a noun with a related, more abstract meaning, e.g. expert → talent (Kgolo, 2014); see the examples below. Note that (2a) and (3a) represent straightforward cases of (singular-to-plural) inflection (without any changes in meaning), and (2b) and (3b) cases of (nominal) derivation without any changes of inflection, as both prime and target are singular forms.

(2) a. *dikgeleke* ‘experts’ – *KGELEKE* ‘expert’

b. *bokgeleke* ‘talent’ – *KGELEKE* ‘expert’

(3) a. *dingaka* ‘doctors’ – *NGAKA* ‘doctor’

b. bongaka ‘medical degree’ – *NGAKA* ‘doctor’

Both inflected and derived primes were orthographically similar in that they fully contained their corresponding targets. Furthermore, the inflectional and derivational prefixes we selected were of the same length (two letters). Unrelated primes were all nouns, parallel to the inflected and derived primes, and were dissimilar in form or meaning to the target words. Additional item properties can be seen from Table 1. To match items for frequency, we extracted word-form frequencies per million from the SetswanaWaC corpus (Otlogetswe, 2012; see www.sketchengine.co.uk; Kilgarriff, Rychly, Smrz, & Tugwell, 2004). The corpus contains 11,496,687 words from over nine thousand texts of different genres (e.g. newspapers and magazines, science books, grammar books, transcriptions of spoken text). As can be seen from Table 1, the inflected, derived, and unrelated primes within the critical set were comparable in length and had similar distributions across prime types, although the frequency of the derived prime words was (unavoidably) lower than the frequency of the inflected (plural-marked) prime words. To assess the potential role of these differences, prime length and frequency were tested for inclusion in all the statistical models we report (Sassenhagen & Alday, 2016); see the section ‘Data Analysis’ below for further details.

Table 1. Mean item characteristics (standard deviation, range) for all sets and prime types.

	WFF	Letters	Overlap	Semantic Relatedness
Prefixation Set (N = 28)				
Inflected Prime	22.00 (33.57, 0-115.50)	7.46 (1.50, 5-11)	0.68 (0.05, 0.57-0.77)	4.75 (0.13, 4.45-4.95)
Derived Prime	8.78 (20.98, 0-89.03)	7.46 (1.50, 5-11)	0.68 (0.05, 0.57-0.77)	4.41 (0.30, 3.95-4.90)
Unrelated	17.18 (22.53, 0.22-111.31)	7.57 (1.62, 5-11)		
Target/Identity Prime	121.87 (249.11; 0.07-1017.8)	5.39 (1.62; 2-9)		
Suffixation Set (N = 28)				
Inflected Prime	19.88 (42.21, 0.07-179.33)	6.25 (0.93, 5-9)	0.51 (0.05, 0.43-0.64)	4.67 (0.12, 4.37-4.85)
Derived Prime	9.21 (29.75, 0-157.49)	6.25 (0.93, 5-9)	0.65 (0.04, 0.59-0.74)	4.54 (0.18, 4.15-4.84)
Unrelated Prime	18.94 (31.98, 0-161.86)	6.25 (1.04, 4-8)		
Target/Identity Prime	154.14 (227.72, 0.89-853.10)	4.25 (0.93, 3-7)		

Table 1. Continued.

	WFF	Letters	Overlap	Semantic Relatedness
Orthographic Control Set (N = 30)				
Word-Final Overlap (N = 15)				
Related	29.31 (71.38, 0.07-282.90)	6.00 (1.07, 4-7)	0.64 (0.06, 0.56-0.78)	
Unrelated	34.81 (49.00, 0.22-137.40)	6.07 (1.22, 4-8)		
Target/Identity Prime	183.43 (418.28, 0.22-1402.00)	4.00 (0.65, 3-5)		
Word-Initial Overlap (N = 15)				
Related	40.63 (68.09, 0.22-200.9)	6.47 (1.19, 5-9)	0.69 (0.07, 0.57-0.8)	
Unrelated	39.43 (67.40, 0.74-241.86)	6.40 (1.18, 5-9)		
Target/Identity Prime	82.73 (143.51, 1.18-409.10)	4.27 (0.96, 3-6)		
Semantic Control Set (N = 30)				
Related	143.32 (367.37, 0.44-2034.6)	4.97 (1.30, 3-7)		4.55 (0.32, 3.65-4.95)
Unrelated	59.76 (89.92, 1.11-421.26)	6.03 (1.56, 4-9)		
Target/Identity Prime	60.60 (102.25, 1.55-485.5)	5.97 (1.50, 4-9)		

The item set testing priming from suffixed words ('suffixation set') comprised prime-target pairs with suffixed inflected and derived prime words. Note that suffixes are more common for verbs than for nouns in Setswana. We therefore tested verbs in this set. Twenty-eight target verbs, ending with the default final vowel *-a*, were preceded by one of four prime types: an identical prime, an inflected prime (with the past-tense suffix *-ile*), a derived prime (with the highly productive stative-formation suffix *-ega*, inclusive of the default final vowel *-a*), and an unrelated prime; see examples in (4) and (5). The derived and inflected suffixes had the same length (viz. three letters), and the derived, inflected, and unrelated prime words were matched in length and frequency as closely as possible. All unrelated primes were verbs. Again, as in the critical prefixation condition, the derived primes were less frequent than the inflected prime words; see Table 1.

(4) a. *supile* 'showed' – *SUPA* 'to show'
b. *supega* 'proven' – *SUPA* 'to show'

(5) a. *thubile* 'broke' – *THUBA* 'to break'
b. *thubega* 'to dissolve' – *THUBA* 'to break'

The orthographic control set included 30 targets, preceded by an identical, an orthographically related, or an unrelated prime. Related and unrelated primes were matched for grammatical class, number of letters, and word-form frequency; see Table 1. All orthographically related primes fully included their corresponding targets, but were otherwise (semantically and morphologically) unrelated to their targets; none of them were pseudo-complex. There were 15 prime-target pairs in which the prime orthographically overlapped with the target word-finally, mimicking orthographic overlap in the critical prefixation set (e.g. *potlana-TLANA* 'small-TO CLIMB'), and 15 pairs with word-initial prime-target overlap, mimicking the suffixation control set (e.g.

elama-ELA 'to incubate-TO FLOW'). To ensure that item pairs in the two morphological sets ('prefixation', 'suffixation') were similar to those of the orthographic control set with respect to orthographic overlap, we applied Davis' (2010) Match Calculator, using the SOLAR Spatial Coding option, to our item pairs. As can be seen from Table 1, the prime-target pairs of the critical prefixation (both inflected and derived) condition had almost the same orthographic overlap ratio as those in the corresponding (word-final) orthographic control set (0.68 vs. 0.64), whereas for the morphological control set ('suffixation'), the orthographic overlap ratio was similar to the corresponding pairs of the (word-initial) orthographic control set for derived pairs (0.65 vs. 0.69), but slightly lower for inflected pairs (0.51 vs. 0.69).

Finally, the semantic control set contained 30 targets, which were preceded by a semantically related prime, in addition to identical and unrelated primes. To select items for this set, we first collected ratings pertaining the degree of semantic relatedness between each related prime-target pair of the critical set (prefixation), the morphological control set, and 53 additional word pairs that were related in meaning but otherwise unrelated, using an online survey in which Setswana native speakers were asked to judge the word pairs on a 5-point semantic rating scale (1 = completely unrelated, 5 = strongly related). All prime-target pairs were distributed across two lists, each containing word pairs with 14 prefixed inflected, 14 prefixed derived, 14 suffixed inflected, and 14 suffixed derived word forms, plus 26 or 27 semantically related pairs, for a total of 82 and 83 pairs in each list. Twenty subjects per list completed the survey. For each pair, we calculated a semantic-relatedness index, corresponding to the mean of all ratings for each pair; see Table 1. We then selected 30 pairs for the semantic control set of our experiment so that their semantic relatedness index was matched to that of the critical set. Related and unrelated prime types in the set were as closely matched as possible in terms of grammatical class, length and frequency (but related primes tended to be more frequent).

Targets were verbs, adjectives, and nouns. In order to mimic the semantic relatedness between both inflected and derived primes and their corresponding targets, half of the semantically related pairs were synonyms (*lebati*-*SETSWALO* 'door-curtain or door placed at an entrance') and half were associates (*alafa*-*LWALA* 'to heal-ill').

The 116 targets from the prefixation set (n = 28), the suffixation set (n = 28), and the two control sets (n = 30 each) were mixed with 304 fillers in a pseudo-randomised order, for a total of 420 pairs in each list. Two to five fillers were presented after an experimental target, so that two experimental targets never occurred one after each other. Of the filler targets, 94 were existing words and 210 were non-existing words, so that a negative response was required in half of the trials. In all fillers, primes were existing words bearing no morphological, orthographic, or semantic relationship to the corresponding targets. Non-words were created replacing 1–3 graphemes of existing Setswana words. In total, only 19.52% of the prime-target pairs in each list were related, either in form, meaning, or morphology.

The critical prefixation set and the suffixation set contained four different prime types (identity, inflected, derived, unrelated), whereas the orthographic and the semantic sets only three (identity, related, unrelated). We created four presentation lists using a Latin Square design, with each list containing only one of the different prime-target pairs from each set, so that no participant would see a target more than once during the experiment. Furthermore, we created four additional lists by reversing the order of item presentation in the four original lists, to compensate for fatigue or training effects. This resulted in a total of eight presentation lists. Each participant was randomly assigned to one of the eight lists. Participants were homogeneously distributed across all lists.

Procedure

Participants were tested in a quiet room. The experiment was run on the experimental software DMDX (Forster & Forster, 2003), which records both RTs in milliseconds and accuracy of responses. Participants were informed that they would see a sequence of words in the middle of the screen, comprising both existing Setswana words and invented words, and that their task was to decide as quickly and as accurately as possible whether each word was an existing word of Setswana or an invented word ('lexical decision'), by pressing a 'yes' or a 'no' button on a gamepad. All participants used their dominant hand for yes-responses and the other hand for no- responses. Each trial began with a 500-millisecond blank screen. A forward mask was then presented, consisting of a number of hashes equal to the number of letters of the prime. The prime word was displayed directly after the mask, for 50 milliseconds, in lower-case letters. Finally, the target appeared on the screen, in upper-case letters; this was presented until the participants' response or for a maximum of 500 milliseconds. Lexical decisions could still be made after disappearance of the target, but with a timeout of 5000 milliseconds after target onset. The next trial started immediately after participants' responses or after a timeout.

The study was approved by the ethical committee of the University of Botswana (application number UBR/ RES/IRB/011).

Data analysis

The experiment yielded accuracy and RT data. The raw RTs were log-transformed to normalise their distribution and reduce the influence of outliers (Ratcliff, 1993). We analysed the accuracy data and the log RT data using, respectively, binary logistic regression models and mixed-effect linear regression models. All models were fitted using the package lme4 (Bates, Mächler, Bolker, & Walker, 2015) in the software

'R', version 3.3.2 (R Development Core Team, 2014). Parameters were estimated with restricted maximum likelihood. In all models, contrasts for the fixed effects were computed from the generalised inverse function (Schad, Hohenstein, Vasishth, & Kliegl, 2020).

For the accuracy data, we tested the effect of Prime Type with four levels for the morphological conditions (unrelated, identity, derived, inflected) and three levels for the control conditions (unrelated, identity, related) on the correctness of responses. Correct responses were coded with '1' and incorrect responses with '0'. The baseline for the fixed effect Prime Type was 'unrelated'.

For the RT data, we first fitted a model on the items from the critical set (prefixation). The model included the fixed effect Prime Type with 'unrelated' used as baseline, so that the model provided estimates of the priming effects with each of the three other primes (identity, derived, inflected) compared to the unrelated prime. We subsequently changed the baseline to 'derived' in order to directly compare inflectional and derivational priming. This model allowed us to answer our main question, i.e. whether it is possible to find significant priming effects for prefixed inflected words, and to additionally check if these yield priming effects of similar magnitude as those from prefixed derived words. Similarly, we tested priming effects with suffixed words, in a model containing the fixed effect Prime Type (unrelated, identity, derived, inflected), selecting 'unrelated' as baseline. We then assessed priming effects in the two control sets. The model testing priming in the orthographic control set contained two fixed factors, Overlap Type (initial, final; baseline = initial) and Prime Type (unrelated, identity, related; baseline = unrelated). This model tested for main effects of Prime Type across different overlap types and main effects of Overlap Type across different prime types, as well as for interactions between the two fixed factors to determine whether priming effects were modulated by the position of the orthographic overlap. Finally, the model testing priming in the semantic control set included the fixed factor Prime Type, with three levels (unrelated, identity, related; baseline = unrelated).

All the models we fitted included random intercepts for subjects and targets. For each model, we additionally tested for inclusion of the two fixed factors 'prime length' and 'word-form frequency', in order to account for the numerical differences in the item characteristics across different sets (see Table 1), as well as of the two individual characteristics 'use of written Setswana' and 'use of written English', to assess whether these interacted with the priming effects. We also tested for inclusion of the fixed factor Trial Number, to account for possible effects of presentation order. We checked whether these additional fixed factors significantly improved the model fit by comparing the model with and the model without the additional factor, by means of the 'anova' R function. For each of the models we fitted, none of these factors improved the model fit, suggesting that they cannot explain our data; hence, they were not included in the models reported in the Results section. With an analogous procedure, we tested for inclusion of the relevant random slopes for 'participants' and 'items' (Matuschek, Kliegl, Vasishth, Baayen, & Bates, 2017). Each best-fit model is described in the Results section.

Data cleaning

Before analysing the data, inspection of the participants' responses to the lexical decision task revealed that of the 85 participants tested, 36 had mean accuracy scores below 60% in either word or non-word trials. These participants had to be excluded from any further analysis, because we cannot be sure that they properly understood the task and/or were able to reliably distinguish between the words and non-words that were presented in the experiment. More generally, the accuracy cut-off that is commonly set for inclusion of participants or items into a masked priming experiment is at least at

70%, even with non-native speakers of a language (see e.g. Crepaldi et al., 2010; Heyer & Clahsen, 2015; M. Li, Jiang, et al., 2017). With exploratory purposes, we applied the criteria and fitted the same type of models described in the previous section to the data from the prefixation and the suffixation sets of the subgroup of 36 participants with reduced accuracy scores. These models did not reveal any significant priming effects, either in the morphological or in the identity conditions[1]. Confirmation for excluding this subgroup of participants comes from the fact they did not even show reliable repetition-priming effects, i.e. facilitation in the identity condition. Repetition priming may be taken as a diagnostic for a participant's sensitivity to related word pairs under masked priming conditions. If a participant does not exhibit facilitated target recognition for an identical word pair, then other more subtle types of relatedness are unlikely to yield any priming effects. Consequently, we are reasonably confident that the visual masked priming technique was indeed unsuitable for examining morphological priming effects in this subgroup of participants.

We also removed items that were correctly recognised in less than 60% of trials, leaving 22 items in the critical prefixation set, 27 items in the suffixation set, 24 in the orthographic control set, and 30 items in the semantic control set. Furthermore, we excluded one participant with an excessively long overall mean RT of more than 2000 ms, which was over 2.5 standard deviations (SDs) above the group mean. For the RT analyses, we excluded timeouts and incorrect responses (10.9% of the experimental items) as well as outliers, i.e. RTs above or below 2.5 SDs from each participant's mean correct log RT per set (1.6% of the remaining experimental trials).

RESULTS

Table 2 presents by-participant mean RTs and accuracy rates for lexical decisions for each set and prime type.

Table 2. By-subject mean RTs in ms and standard errors (back-transformed from log RTs), priming effects, and accuracy scores for all sets and prime types.

Prime Type	Mean RT (SE)	Priming Effect	Accuracy
Prefixation Set			
Identity	701 (81)	63	91.6%
Derived	720 (73)	44	91.7%
Inflected	733 (83)	31	94.0%
Unrelated	764 (87)		94.8%
Suffixation Set			
Identity	694 (66)	61	92.3%
Derived	738 (63)	17	94.4%
Inflected	735 (62)	20	90.7%
Unrelated	755 (65)		91.6%
Orthographic Control Set: Final Overlap			
Identity	710 (93)	63	89.4%
Related	801 (89)	-28	87.2%
Unrelated	773 (85)		91.8%
Orthographic Control Set: Initial Overlap			
Identity	815 (112)	34	79.9%
Related	814 (102)	35	82.0%
Unrelated	849 (126)		74.0%
Semantic Control Set			
Identity	789 (70)	43	88.8%
Related	806 (66)	26	86.7%
Unrelated	832 (64)		88.3%

As regards the *accuracy* scores, Table 2 indicates a substantial increase in accuracy in one condition only, namely following related primes in the word-initial overlap subset of the orthographic control set (8% increase). This is the only comparison that was statistically significant in the models we fitted on the accuracy data (β = 0.5504, SE = 0.2589, t = 2.126), possibly due to the relatively low accuracy score in the unrelated condition (74%) in this particular case.

With respect to the *RT data*, consider first the critical ('prefixation') set which, according to Table 2, yielded facilitatory priming effects with all types of primes (identity, derived, inflected). The output of the linear-mixed effect model testing for priming effects on target RTs in this condition is provided in Table 3. The model confirmed significant facilitation following related compared to unrelated primes for identity, derived, and inflected primes. By changing the baseline for Prime Type from 'unrelated' to 'derived', we determined that the numerical difference between derivational and inflectional priming (13ms) was not significant (β= 0.0116, SE=0.0219, t=0.531). Taken together, these results indicate reliable priming from both prefixed inflected and prefixed derived words, without any evidence for a difference between the two.

Table 3. Fixed effects from the model of the prefixation set.

	β	SE	*t*
(Intercept)	6.6109	0.0453	146.059 *
Prime Type: Identity vs. Unrelated	-0.0888	0.0218	-4.079 *
Prime Type: Derived vs. Unrelated	-0.0575	0.0211	-2.724 *
Prime Type: Inflected vs. Unrelated	-0.0459	0.0218	-2.105 *

Formula in R: log(RT) ~ Prime Type + (1 | subject) + (1 | item)

As regards the suffixation set, we obtained a significant repetition-priming effect in the identity condition, whereas the small numerical trends for facilitation in RTs following derived and inflected primes did not turn out to be significant. The output of the model is presented in Table 4.

Table 4. Fixed effects from the models of the suffixation set.

	β	SE	*t*
(Intercept)	6.6040	0.0330	200.335 *
Prime Type: Identity vs. Unrelated	-0.0896	0.0190	-4.726 *
Prime Type: Derived vs. Unrelated	-0.0290	0.0185	-1.571
Prime Type: Inflected vs. Unrelated	-0.0277	0.0191	-1.449
Formula in R: log(RT) ~ Prime Type + (1 | subject) + (1 | item)			

In a set of additional analyses, we assessed effects of Prime Type on RT data in the two control sets. The output of the corresponding models is presented in Table 5. The orthographic control set yielded significant identity priming across both subsets of word-final and word-initial items, with no interaction between Overlap Type (final vs. initial) and Prime Type (identity vs. unrelated). Instead, we found a contrast between priming with word-initial and word-final overlapping primes, yielding a significant interaction of Overlap Type (final vs. initial) by Prime Type (related vs. unrelated) in the statistical model. This is due to the fact that word-initial orthographic overlap (mimicking suffixation) led to a significant facilitatory priming effect, while word-final overlap (similar to prefixation) led to a non-significant trend towards inhibition. Finally, the semantic set also produced significant repetition priming, but no semantic priming.

Table 5. Fixed effects from the models of the orthographic and semantic control sets.

	β	SE	t
Orthographic Control Set			
Overall Model			
(Intercept)	6.6793	0.0330	202.635 *
Overlap Type: Final vs. Initial	-0.0981	0.0428	-2.292 *
Prime Type: Identity vs. Unrelated	-0.0596	0.0211	-2.820 *
Prime Type: Related vs. Unrelated	-0.0250	0.0213	-1.175
Overlap Type (Final vs. Init.) * Prime Type (Id. vs. Unr.)	0.0110	0.0424	0.260
Overlap Type (Final vs. Init.) * Prime Type (Rel. vs. Unr.)	0.0991	0.0426	2.326 *
Formula in R: log(RT) ~ Overlap Type * Prime Type + (1 + Overlap Type | subject) + (1 | item)			
Word-Final Overlap			
(Intercept)	6.6303	0.0411	161.151 *
Prime Type: Identity vs. Unrelated	-0.0622	0.0341	-1.827
Prime Type: Related vs. Unrelated	0.0181	0.0292	0.618
Formula in R: log(RT) ~ Prime Type + (1 + Prime Type | subject) + (1 | item)			
Word-Initial Overlap			
(Intercept)	6.7280	0.0381	176.404 *
Prime Type: Identity vs. Unrelated	-0.0676	0.0320	-2.115 *
Prime Type: Related vs. Unrelated	-0.0737	0.0309	-2.383 *
Formula in R: log(RT) ~ Prime Type + (1 | subject) + (1 | item)			
Semantic Control Set			
(Intercept)	6.7057	0.0341	196.622 *
Prime Type: Identity vs. Unrelated	-0.0541	0.0170	-3.179 *
Prime Type: Related vs. Unrelated	-0.0117	0.0171	-0.683
Formula in R: log(RT) ~ Prime Type + (1 | subject) + (1 | item)			

Discussion

Our main finding from the current study is that prefixed inflected word forms yield significant priming effects that are similar in magnitude to those of prefixed derived words. Crucially, these priming effects are genuinely morphological in nature, since additional control prime-target pairs that were not morphologically related, but exhibited the same degree of orthographic and semantic overlap as the critical prefixed word forms with their targets, did not generate any significant priming effects. Previous studies found that inflected and derived words yield reliable morphological priming effects, at least in native speakers of a given language (e.g. Kirkici & Clahsen, 2013; Silva & Clahsen, 2008). Yet, this was exclusively investigated with suffixed words. The current findings show that this extends to prefixed word forms. We interpret these morphological priming effects to reflect the presence of shared morphological constituents in the prime and in the target, as illustrated in the critical prime-target pairs (2a, 2b), shown here again for convenience: *dikgeleke* → *KGELEKE* 'experts' → 'expert' and *bokgeleke* → *KGELEKE* 'talent' → 'expert'. In these word pairs, the prime word's stem (-*kgeleke* 'expert') is repeated in the target word. Stem-repetition priming effects of this kind have been taken to result from morphological decomposition; see Marslen-Wilson (2007) for a review. In the present case, prefixed inflected and derived words are decomposed into their morphological constituents (e.g. di+kgeleke, bo+kgeleke) by which the base stem is isolated and directly primes the target stem. Thus, while the processing of prefixed words may somehow incur extra effort compared to suffixed words, as suggested by unprimed lexical decision and eye-tracking studies (Beauvillain, 1996; Bergman et al., 1988; Colé et al., 1989; Ferrari Bridgers & Kacinik, 2017), the purportedly disadvantageous word-final position of the stem within a prefixed word form does not preclude reliable morphological priming.

As regards the suffixation set, we obtained some numerical facilitation from derivationally and inflectionally related primes, but no statistically significant priming effects. Given the large number of previous studies that reported reliable masked priming effects from suffixed words in different languages (e.g. Kirkici & Clahsen, 2013; Silva & Clahsen, 2008), the lack of such priming in Setswana is certainly unexpected. Explaining why a predicted result was not obtained in a particular experiment is always difficult. Here, we offer some possible reasons. Firstly, Kgolo and Eisenbeiss (2015), the only previous masked priming study on Setswana, reported that the presence of unprimed material in the target (i.e. when the target is not fully embedded in the prime, but contains additional morphemes) substantially reduces the magnitude of the priming effects, turning an otherwise significant priming effect, in their case for prefixed words, into an unreliable numerical trend. This contrast also applies to our experiment. Whilst in the critical set (for prefixed words) the target words were fully included in their primes (e.g. *dikgeleke* – *KGELEKE* 'experts – expert'), this was not the case for the suffixed words in the morphological control set (e.g. *tshubile* – *TSHUBA* 'burned-to burn'). Hence, the lack of significant priming for suffixed words in our experiment may be due to the targets containing unprimed material in this condition. It should be noted, however, that masked priming experiments for other languages have revealed significant priming effects from suffixed words despite unprimed material in the target, for example for *adorable* – *adore* in English (McCormick, Rastle, & Davis, 2008) or for *geändert* – *ändern* 'changed – (to) change' in German (Jacob et al., 2018). Yet, specific properties of Setswana morphology may be responsible for the lack of reliable priming effects from suffixed words in our experiment. Unlike in European languages, suffixation is less common than prefixation in Setswana, due to the prominent role of prefixation in grammatical agreement. Perhaps suffixed words are therefore less prone to be decomposed into their morphological constituents than prefixed ones, hence the lack of priming for suffixed words. We readily admit, however, that these considerations are tentative and that the processing of suffixed words in Setswana (and other Bantu languages) requires further investigation.

In the orthographic and semantic control sets, we found both expected and unexpected results. Previous research has shown that *semantically* related but otherwise unrelated prime-target pairs do not produce reliable priming effects under masked priming conditions; see Heyer and Kornishova (2018) for a recent review. This was confirmed for our Setswana semantic control set, which yielded significant repetition-priming effects but no semantic priming. Furthermore, previous research on languages with alphabetic script systems has shown that pure *orthographic* relatedness does also not yield reliable masked priming effects, at least in native speakers; see Nakano et al. (2016) for a review. In the present study, however, we found significant orthographic priming effects. This is more in line with previous research on non-native speakers (Diependaele et al., 2011; Feldman et al., 2010; Heyer & Clahsen, 2015; J. Li, Taft, et al., 2017; J. Li & Taft, 2019; M. Li, Jiang, et al., 2017) and heritage speakers (Jacob & Kırkıcı, 2016). There is evidence that such orthographic priming effects arise when speakers have relatively low proficiency in a given language, i.e. when it is their weaker language (J. Li, Taft, et al., 2017). Because Setswana is mostly a spoken language that is not commonly used for written communication, this reasoning may also apply to our study, as the speakers we tested may be more proficient in reading in English than in Setswana. Importantly, however, although there is at least one previous L2 study that has reported orthographic priming with word-finally overlapping pairs (J. Li & Taft, 2019), in the present study the orthographic priming effect was restricted to word-initial overlap (equivalent to suffixed but not prefixed words). Hence, orthographic relatedness cannot account for the morphological priming effect we found for prefixed words.

A final question concerns how our findings fit in with current models of morphological processing, in particular with accounts of morphological processing during reading: affix stripping, single-route full decomposition, and edge-aligned embedded word activation. It is true that the results for the critical condition (which tested priming effects from prefixed words) are consistent with these models. Furthermore, the results from the semantic control condition (which did not yield any reliable facilitation) are also in line with these models, indicating that the masked priming effects obtained for (prefixed) derived and inflected words are not due to pure meaning overlap. If, however, the results from the suffixation set and the orthographic control set are included into the picture, the three models turn out to be less successful. First, while all three models differ for the mechanisms they postulate to explain morphological priming effects (respectively, stripping off of affixes, rule-based decomposition into basic morphemes, and activation of embedded words), they all clearly predict parallel priming effects with prefixed and suffixed words. Therefore, all three models would need some refinement to account for why we found priming for prefixed but not for suffixed words. As for our results in the orthographic control set, these are particularly problematic for the edge-aligned embedded word activation account, according to which embedded words are activated at both edges of a given letter string, even when the latter is not morphologically complex (e.g. *cashew*, which contains *cash*). This should result in priming effects with suffixed and prefixed words, but also with word-initially and word-finally overlapping prime-target pairs, at least when the lexical competition between the two is absent, i.e. with non-word primes (e.g. **flexint-flex*), or reduced, such as in speakers with lower proficiency (see J. Li, Taft, et al., 2017; Taft, Li, & Beyersmann, 2018), as may be the case of our Setswana speakers. However, we found priming for prime-target pairs that overlap word-initially (e.g. *elama-ELA* ‘to incubate- TO FLOW'), but not for those that overlap word-finally (*potlana-TLANA* 'small-TO CLIMB'), which is difficult to explain by this account.

Taken together, while our main findings on prefixation priming in Setswana are in line with current models of morphological processing, none of these models provides a complete account of the experimental data, in that some of the additionally tested control sets produced unexpected results. Further experimentation on Setswana is specifically needed on suffixed prime words and on the role of orthographic relatedness under masked priming conditions.

CONCLUSION

Relative to the wide range of typologically different languages, previous experimental psycholinguistic research has been strongly biased towards European languages, mainly English, and has particularly neglected African languages. This has not only led to artificial gaps in the linguistic landscape, but also to psycholinguistic models being empirically underdetermined. The present study examined Setswana, a Bantu language with a rich system of prefixes that allows for testing prefixed inflected word forms, which we investigated using the masked priming technique. Current models of morphological processing ('affix stripping', 'single- route full decomposition', 'embedded word activation') predict reliable priming effects for both inflected and derived word forms, irrespective of whether these are suffixed or prefixed. However, due to the lack of inflectional prefixes in the languages that have typically been tested in psycholinguistic experiments, previous experimental studies have examined priming from inflectional suffixes, but not from prefixes. The current study is the first that investigated masked priming effects with prefixed inflected word forms and additionally compared them to those obtained from prefixed derived words. We found reliable priming effects for both types of prefixed forms, which were also found to be dissociable from semantic and orthographic priming. We conclude that prefixation priming effects are genuinely morphological in nature, due to the decomposition of both inflected and derived word forms into their morphological constituents.

NOTES

1. In the critical ('prefixation') set, all prime types, including identity primes, yielded non-significant tendencies for inhibition (identity: -9 ms, t = -0.767; derived -23 ms, t = 1.306; inflected -26ms, t = 1.094). In the item set testing suffixed words, there was a non-significant numerical tendency for facilitation following identity and inflected primes (identity: 18 ms, t = -1.748; inflected: 10 ms t = -0.710) and a non-significant tendency for inhibition with derived primes (-9ms, t = 0.408).

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Appendix

Experimental items

1. Prefixation set

Unrelated Prime	English Translation	Derived Prime	English Translation	Inflected Prime	English Translation	Target	English Translation
kutlwano	agreement	botsotsi	trickery	ditsotsi	petty criminals	TSOTSI	petty criminal
matlhare	leaves	bonyatsi	concubineship	dinyatsi	concubines	NYATSI	concubine
legetla	shoulder	bongaka	medical degree	dingaka	doctors	NGAKA	doctor
temogo	realization	bonoga	sneakiness	dinoga	snakes	NOGA	snake
maitseboa	evening	botshwene	stupidity	ditshwene	baboons	TSHWENE	baboon
lonyatso	contempt	botshipi	hardness, hard-heartedness	ditshipi	metals	TSHIPI	metal
leseka	bracelet	bopodi	goat-like behavior	dipodi	goats	PODI	goat
modumo	sound	bonku	submissiveness	dinku	sheep (plural)	NKU	sheep
selwana	utensil	bontsa	dog-like behavior	dintsa	dogs	NTSA	dog
foraga	bait	bokatse	coolness	dikatse	cats	KATSE	cat
leroo	paw	bopelo	kind heartedness	dipelo	hearts	PELO	heart
ntlole	spring hare	bonako	rapidity	dinako	times	NAKO	time
sekgwama	purse	boagente	law	diagente	lawyers	AGENTE	lawyer
setshwakga	lazy person	bokaedi	supervision	dikaedi	instructions	KAEDI	instruction
motsoko	tobacco	bontlha	part	dintlha	points	NTLHA	point
sehuba	chest	bojelo	manger	dijelo	crops	JELO	crop

Unrelated Prime	English Translation	Derived Prime	English Translation	Inflected Prime	English Translation	Target	English Translation
ntlwana	room	bokaelo	meaning	dikaelo	illustrations	KAELO	illustration
lemphorwana	squab bird	bopalamente	parliamentary duties	dipalamente	parliaments	PALAMENTE	parliament
mogatsaka	my spouse	bokgeleke	talent	dikgeleke	experts	KGELEKE	expert
lebogo	hand	bonaga	undeveloped, wild behavior	dinaga	forests	NAGA	forest
mogotlha	livestock track	bongwetsi	the state of being a daughter-in-law	dingwetsi	daughters-in-law	NGWETSI	daughter-in-law
moroba	fun	bokala	disobedience , stubbornness	dikala	branches	KALA	branch
sefapaano	cross	bophekgwe	bully behavior	diphekgwe	bullies	PHEKGWE	bully
serurubele	butterfly	botshimega	state of championship	ditshimega	champions	TSHIMEGA	champion
kgololo	liberation	bokwete	bossiness, pomp	dikwete	braggarts	KWETE	braggart
sekgono	elbow	bokwana	gentle / benevolent person, brisket	dikwana	lambs	KWANA	lamb
pharologanyo	difference	bochekwane	state of being a naughty person	dichekwane	naughty persons	CHEKWANE	naughty person
molwetsi	patient	botshomi	friendship	ditshomi	pals	TSHOMI	pal

2. Suffixation set

Unrelated Prime	English Translation	Derived Prime	English Translation	Inflected Prime	English Translation	Target	English Translation
thunya	shoot	rekega	ability to be bought	rekile	bought	REKA	buy
latswa	lick	ratega	loveable	ratile	loved	RATA	love
goduma	sip	supega	proven	supile	showed	SUPA	show
relela	slip	rutega	learn a lot	rutile	taught	RUTA	teach
fefera	sift	robega	collapse, break	robile	broke	ROBA	break
setla	pound	agega	buildable	agile	built	AGA	build
huduga	move house	lomega	biteable	lomile	bit	LOMA	bite
rapela	pray, beg	lebega	appear, smart	lebile	looked	LEBA	look
tuka	burn	kamega	ability to be combed	kamile	combed	KAMA	comb
gobetse	hurt	tlhophega	choseable	tlhophile	selected	TLHOPHA	select
tsoga	wake up	rerega	preachable	rerile	preached	RERA	preach
potela	shirk	loega	ability to be bewitched	loile	bewitched	LOA	bewitch
apola	take off clothes	romega	ability to be sent	romile	sent	ROMA	send
tabola	scoop up	segega	cutable	segile	cut	SEGA	cut
bekenya	flash	senkega	searchable	senkile	searched	SENKA	search

Unrelated Prime	English Translation	Derived Prime	English Translation	Inflected Prime	English Translation	Target	English Translation
romela	send	bopega	ability to be molded	bopile	molded	BOPA	mold
tsadisa	mate	bokega	ability to be praised	bokile	recited	BOKA	recite
tlhodia	make noise	batlega	ability to be wanted / desired	batlile	wanted	BATLA	want
tlhagola	dig up for seeds	phuthega	ability to be gathered	phuthile	gathered	PHUTHA	gather
ratela	sneak upon	logega	plaitable	logile	plaited	LOGA	plait
timela	stray	lemega	arable	lemile	cultivated	LEMA	cultivate
olela	collect garbage	kubega	clearable	kubile	cleared	KUBA	clear
kgatlha	amuse	remega	ability to be chopped	remile	chopped	REMA	chop
rotha	drop	epega	digable	epile	dug	EPA	dig
dikologa	rotate	thubega	dissolve	thubile	broke	THUBA	break
duduetsa	ululate	tshubega	combustible	tshubile	burned	TSHUBA	burn
boulela	become jealous	boifega	feared, ability to be feared	boifile	feared	BOIFA	fear
thakanya	add, mix	ruega	ability to be reared	ruile	reared	RUA	rear

3. Orthographic control set

Unrelated Prime	English Translation	Related Prime	English Translation	Target	English Translation
Word-Final Overlap					
tshetlha	brown	kgaraga	thick	RAGA	kick
nnye	small	kima	fat	IMA	conceive
nyelela	disappear	gwaripa	dirty, red and white (animal colour)	RIPA	tear up, shred
khibidu	red	potlana	small	TLANA	climb
fudua	stir	mosha	new	OSHA	pause
sesane	thin	putswa	blue	TSWA	come out
goga	pull	tuba	fawn	UBA	throb
raela	tempt	ribega	turn upside-down	BEGA	report
ramaga	red-and-white mottled (animal colour)	gadika	fry	DIKA	gang up
koloba	get wet	dumela	agree	MELA	grow
felela	end, finish	sobotla	march on sth	BOTLA	burp
swapola	snatch	shenama	grin	NAMA	sit with legs stretched out
tletse	full	rakana	meet	KANA	pack
phepha	clean	kgora	be full	ORA	warm oneself at a fire
tshabega	fiery	laletsa	invite	LETSA	call
Word-Initial Overlap					
atamela	come closer	kgaogano	divide	KGAOGA	break
tsoma	hunt	lekana	equal	LEKA	try
alola	chase	gakala	worsen	GAKA	baffle
tlwaela	disrespect	bolaya	kill	BOLA	rot

Unrelated Prime	English Translation	Related Prime	English Translation	Target	English Translation
somola	pull out	sikara	carry on shoulder	SIKA	scout
dubega	kneadable	lelala	look up	LELA	cry
boela	return	ilela	revere	ILE	gone
masweu	white	elama	incubate	ELA	flow
hibidu	red	monate	delicious	MONA	suck
kgweba	red and white in small spots	swaana	whitish	SWAA	pound meat
maruru	cold	sokame	slanted	SOKA	strangle
namagadi	female	tshwaana	white	TSHWAA	mark, brand
akaretsa	include	galalela	shiny	GALA	shout
rurifatsa	prove	phaphathi	flat	PHAPHA	be forward
tseega	takeable	bogale	sharp, angry, fierce	BOGA	suffer

4. Semantic control set

Unrelated Prime	English Translation	Related Prime	English Translation	Target	English Translation
kgama	strangle	betsa	beat	ITAYA	beat
botlhoko	bitter, painful	pagama	climb	NAMELA	climb
tsewa	be married	lekola	check	TLHOLA	check
fepa	provide for	ema	wait	LETA	wait
tsholetsa	lift	robala	sleep	THULAMEL A	fall sleep
okomela	peep in	akanya	think	GOPOLA	think
solofela	hope, expect	roga	insult	TLHAPATSA	insult
rora	roar	fitlha	hide	BIPA	hide
mogwe	son-in-law	kobo	blanket	LEPAI	blanket
noko	porcupine	borotho	bread	KUKU	cake
kotsi	accident	rre	father	NTATE	father

Unrelated Prime	English Translation	Related Prime	English Translation	Target	English Translation
rotwe	large male monkey	mogala	rope	KGOLE	rope
lelapa	home, family	noka	waist	LETHEKA	waist
setlhare	tree	lebati	door	SETSWALO	curtain or door placed at an entrance
letsogo	arm	buka	book	LOKWALO	book
ananya	exchange	alafa	sure, heal	LWALA	ill
makgapha	shameful	fokotsa	reduce, decrease	BOTLANA	small
mosi	smoke	godisa	expand, nurture	TONA	large, big
bodule	ripe	gotlha	scrub	BORETHE	smooth
magwata	rough	sitwa	cold	TSIDIDI	cold
phatshwa	black-and-white spotted (animal colour)	nwa	drink	NYORILWE	thirsty
mokoto	stew made from different meats	sefela	hymn	KEREKE	church
semela	plant	kgwele	ball	LEBALA	football ground
mmidi	corn	mooki	nurse	LEMAO	injection
sekipa	t-shirt	tswina	honey	NOTSHE	bee
sekgwa	bush	tee	tea	KOMOKI	cup
ntsi	fly	loso	death	KESI	coffin
botlhokwa	importance	koloi	car	LEOKWANE	fuel
moko	bone marrow	lee	egg	KOKO	chicken
masilo	ghost	sekamo	comb	MORIRI	hair

5. Publication III

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Derivational morphology in agrammatic aphasia: A comparison between prefixed and suffixed words

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ABSTRACT

Although a relatively large number of studies on acquired language impairments have tested the case of derivational morphology, none of these have specifically investigated whether there are differences in how prefixed and suffixed derived words are impaired. Based on linguistic and psycholinguistic considerations on prefixed and suffixed derived words, differences in how these two types of derivations are processed, and consequently impaired, are predicted. In the present study, we investigated the errors produced in reading aloud simple, prefixed, and suffixed words by three German individuals with agrammatic aphasia (NN, LG, SA). We found that, while NN and LG produced similar numbers of errors with prefixed and suffixed words, SA showed a selective impairment for prefixed words. Furthermore, NN and SA produced more errors specifically involving the affix with prefixed words than with suffixed words. We discuss our findings in terms of relative position of stem and affix in prefixed and suffixed words, as well as in terms of specific properties of prefixes and suffixes.

Keywords: Broca's aphasia; morphological decomposition; morphological errors; derivation; prefixes.

INTRODUCTION

A series of studies on acquired language impairments have focused on linguistic morphology, i.e., the domain of linguistics that is concerned with how complex words, such as compounds (e.g., *paycheck*), derived words (*payment*), and inflected words (*pays*), are formed and internally structured. These studies involved individuals whose comprehension or production of complex words, as compared to simple words, is impaired. This condition is referred to as "morphological impairment" and it has mainly been reported in individuals with agrammatic aphasia, generally of Broca's type, as well as in individuals with deep or phonological dyslexia (e.g., Luzzatti et al., 2001; Rastle et al., 2006; Semenza and Mondini, 2015). Impairments of morphology have also been reported in cases of fluent aphasia ("jargon aphasia": Caplan et al., 1972; Semenza et al., 1990), as well as in other neuropsychological disorders, such as semantic dementia (Auclair-Ouellet et al., 2016a, b) or neglect (Semenza et al., 2011; Marelli et al., 2013; Reznick and Friedmann, 2015). In production, morphological impairments are characterized by so-called "morphological" or "constituent" errors, i.e., errors that affect one of the constituent morphemes, while sparing the other. Examples are morpheme substitutions and omissions, affecting stems (e.g., «baseball» or «ball» instead of *volleyball*) or affixes («player» or «play» instead of *playful*), and semantic paraphasias (e.g., «without contact» instead of *contactless*). The label "morphological error" is generally found in studies focusing on derivation or inflection, referring to errors that affect affixes while sparing stems. Instead, the label "constituent error" is more often found in studies that focus on compounds, to describe errors involving one of the stems. Morphologically based errors have been taken as evidence that complex words are accessed and represented in a decomposed fashion (e.g., *playful* [play][-ful]), i.e., based on the single constituents of which they are composed (Semenza and Mondini, 2015).

Studies investigating the impairment of derived words have mostly focused on the case of suffixed forms, e.g., words such as *payer* in which the affix follows the stem (e.g., Rastle et al., 2006). Instead, prefixed words such as *prepay*, in which the affix is placed before the stem, have been comparably neglected. A study specifically focusing on derivation by prefixation is the one by Semenza et al. (2002). The authors tested two speakers of Slovenian with non-fluent aphasia in reading aloud, repetition, and writing to dictation tasks. The two participants produced large number of errors which preserved the prefix while affecting the stem, while cases in which the prefix was substituted or omitted were comparably less frequent. This is an unusual pattern for morphological errors with derived words, at least with suffixed words, for which it is generally the stem that is preserved while the affix is affected (Kay, 1988; Miceli and Caramazza, 1988; Rastle et al., 2006). Unfortunately, because the study did not include suffixed words, we do not know whether their preservation of affixes was a general characteristic of their impairment or, on the contrary, this pattern was restricted to prefixed words. Furthermore, all the prefixes included in the study were at the same time existing Slovenian prepositions, and hence free morphemes, which possibly makes the stimuli more similar to compounds. Other studies have tested sets of prefixed words in addition to sets of suffixed words (e.g., Job and Sartori, 1984; Kay, 1988; Hamilton and Coslett, 2008). These have all reported impaired use of prefixation in addition to impaired suffixation. Yet, none of them has specifically compared prefixed to suffixed words to investigate whether there are differences in how they are impaired.

The lack of studies on acquired morphological disorders directly comparing prefixed and suffixed words is particularly striking if we consider that differences between these two types of derived words have been described both in the linguistics and in the psycholinguistics literature. From a linguistic point of view, prefixes and suffixes have been claimed to serve different functions. This claim is mostly based on the notion of "head", i.e., the constituent that determines the grammatical properties (such as gender or word class) of the complex word. While, in suffixed words, it is generally the suffix that functions as head, the head of prefixed words is generally their stem, as predicted by Williams' (1981) "Right-Hand Head Rule", according to which the head tends to be the most right-hand constituent (but note that there are some exceptions, since prefixes can sometimes be heads, e.g., *en-* in *encourage*). Based on this difference between prefixes and suffixes, some linguists have claimed that derivation by prefixation and derivation by suffixation should be classified as two distinct types of word-formation processes (e.g., Kastovsky, 2005). When it comes to the typological distribution of prefixing and suffixing morphology in the world's languages, a universal preference for suffixation has been observed (Greenberg, 1963). Cutler et al. (1985) have explained this preference in terms of the cognitive mechanisms underlying language processing: processing complex words is easier when the lexical-semantic information carried by the stem comes in the first, and most salient, portion of the word, followed by the affix, which rather serves the processing of larger syntactic and semantic units.

Psycholinguistic evidence on the processing of prefixed derived words is mixed. A number of visual word recognition studies using the masked priming technique have reported significant priming effects for prefixed words (e.g., Diependaele et al., 2009; Kazanina, 2011; Ciaccio and Clahsen, 2020), i.e., shorter lexical decision times to target words when these are preceded by a prefixed prime (e.g., *prepay-pay*) as compared to a baseline condition (unrelated prime: *precook-pay*). Morphological priming effects have been taken as a diagnostic of efficient morphological decomposition of the prime into affix and stem (e.g., [pre-][pay]), which leads to pre-activation of the target (*pay*) before it is actually presented (Marslen-Wilson, 2007). However, there is also evidence that stem access or, more in general, morphological decomposition may be delayed or more costly in prefixed words as compared to suffixed words. In lexical decision tasks, Ferrari Bridgers and Kacinik (2017) found that prefixed words elicit longer response latencies than suffixed words. Similarly, Bergman et al. (1988) reported that, while suffixed and pseudo-suffixed words have similar recognition times, suggestive of automatic stem access, pseudo-prefixed words are recognized more slowly than prefixed words. Finally, Colé et al. (1989) found cumulative root frequency effects on lexical decision times in the case of suffixed words, but not in prefixed words, while Beauvillain (1996) found effects of root frequency on first fixation durations for suffixed words, but only in later measures such as second fixation durations for prefixed words. All these findings have been explained in terms of more effortful morphological decomposition of prefixed words as compared to suffixed words. Prefixes and suffixes may also be processed differently because of the information they encode, with prefixes mostly encoding semantic information, and suffixes additionally carrying a grammatical function. For example, Beyersmann et al. (2015) found that, in a letter identification task, reaction times were longer when the target letter was embedded in a suffix than in a non-morphological ending, while response times for letters contained in prefixes and pseudo-prefixes did not differ. The authors concluded that suffixes, but not prefixes, are identified as sub-lexical chunks during reading, which they explained in terms of the different functions of prefixes and suffixes.

Investigating how prefixed and suffixed words are impaired in acquired morphological disorders can help better understand whether there are differences in how they are processed. Indeed, previous research on morphological impairments have highlighted differences between different types of complex words that would not have been detected in some psycholinguistic tasks, especially in the most widespread task in morphological processing research, namely masked priming. For example, differences between derived and inflected words have been reported in acquired language impairments (e.g., Tyler and Cobb, 1987; Miceli and Caramazza, 1988), although masked priming effects with derived and inflected primes have been consistently shown to be similar in magnitude, at least in adult native speakers (e.g., Jacob et al., 2018). Similarly, while the distinction between compound head and modifier does not modulate masked morphological priming effects (e.g., Duñabeitia et al., 2009; Beyersmann et al., 2018), this has been shown to play a role for morphological impairments, in which head constituents are retained better than modifiers (Jarema et al., 2010; Semenza et al., 2011; Marelli et al., 2013). An additional advantage of investigating morphologically complex words in acquired language impairments is that it is possible to obtain data from naturalistic tasks, such as reading aloud, without needing sophisticated and relatively artificial experimental settings.

THE PRESENT STUDY

A relatively large number of studies have investigated dissociations in the impairment of different types of complex words in acquired morphological disorders (e.g., Tyler and Cobb, 1987; Miceli and Caramazza, 1988; Luzzatti et al., 2001; Penke and Krause, 2002; Hamilton and Coslett, 2008; Marusch et al., 2012). However, none of these have specifically focused on the distinction between derivation by prefixation and by suffixation. As a consequence, we do not know if and to what extent morphological impairments affect all derived words in the same way or, on the contrary, there are differences in how prefixed and suffixed words are impaired. Therefore, the present study specifically investigated errors in reading aloud prefixed and suffixed words in subjects with acquired morphological impairments. We did so by taking advantage of the rich derivational morphology of German, which, compared to other Indo-European languages, has a larger inventory of derivational prefixes (see e.g., Smolka et al., 2014; Günther et al., 2019).

We recruited German individuals with agrammatic aphasia, which is characterized by impaired use of grammatical materials such as function words and inflected forms (Goodglass and Menn, 1985) as well as by impaired production of morphologically complex words (Semenza and Mondini, 2015). Speakers with agrammatic aphasia have been shown to vary consistently in the numbers and types of errors that they produce with complex words (Miceli et al., 1989). The present study extends the current evidence by investigating whether and how errors vary systematically for prefixed and suffixed derived words, and if such error patterns can be predicted based on the differences between prefixed and suffixed words that have been described in the linguistics and psycholinguistics literature.

The question whether prefixed and suffixed words are impaired in the same way is not trivial. On the one hand, we might expect that the different properties of prefixed and suffixed words have consequences on how these are impaired. On the other, it is also possible that morphological impairments equally affect all derivational phenomena, i.e., all words in which a derivational affix is added to a stem, irrespective of the order in which these two constituents occur or of the different properties of prefixes and suffixes. Based on previous psycholinguistic evidence for differences between prefixed and suffixed words in language-unimpaired populations, we regarded the former hypothesis as more promising than the latter.

In the present study, we investigated the numbers and types of errors produced in reading aloud prefixed and suffixed words. We first asked the question whether individuals with morphological impairments produce more errors with, respectively, prefixed and suffixed words as compared to simple words. In line with the typical profile of a morphological impairment (e.g., Job and Sartori, 1984; Rastle et al., 2006; Lorenz and Zwitserlood, 2014), we expected both prefixed and suffixed words to yield more errors than simple words. However, if it is true that processing prefixed words is more costly than processing suffixed words because of the word-final position of the stem (Bergman et al., 1988; Colé et al., 1989; Beauvillain, 1996; Ferrari Bridgers and Kacinik, 2017), then prefixed words may be more impaired than suffixed words. We then focused on the types of errors produced, and specifically on the likelihood of producing an error specifically affecting the prefix or the suffix. Because suffixes and prefixes both contribute to the meaning of the derived word but suffixes also have a more prominent grammatical function, prefixes may be more prone to be lost than suffixes. This should lead to a larger number of affix errors (possibly omissions), with prefixes compared to suffixes. Finally, if stems in prefixed words are less accessible than stems in suffixed words, these may also be less retained, leading to more errors on stems in prefixed than in suffixed words.

METHODS

Participants

Three German individuals (NN, LG, SA) participated in the study. They were recruited through the database of persons with aphasia (PwAs) of the Linguistics Department of the University of Potsdam, based on their diagnosis for aphasia of Broca's type. Biographic information as well as details about the participants' language impairment are provided in Table 1. All PwAs' spontaneous speech was characterized by the typical symptoms of agrammatic speech: simplified, incomplete or ungrammatical sentences, mostly main clauses with no or few subordinate clauses, often missing verbs or verbal inflection. All PwAs were well oriented in space and time and had normal or corrected-to-normal vision. None of them suffered from visual neglect. They were all informed about the aims and contents of the study and signed a written consent form.

Table 1. PwAs' biographic information.

Information	NN	LG	SA
Gender	M	M	F
Age	63	75	50
Education	university degree	vocational training	vocational training
Handedness	left	right	right
Lesion Hemisphere	right	left	left
Time Post Onset	22; 4	19; 11	15; NA
Speech Output	agrammatic	agrammatic	agrammatic
Other Impairment(s)	mild dysarthria	--	--

The PwAs were previously assessed by means of the Aachen Aphasia Test (*Aachener Aphasie Test*; AAT; Huber et al., 1983). Results from the sub-tests on repetition, written language, naming, and comprehension are provided in Table 2. All participants globally showed a profile of mild-to-medium aphasia, though with some differences between individuals and tasks. NN resulted only mildly impaired in language comprehension, and considerably less impaired than both LG and SA. In written language tasks, NN's impairment resulted to be medium-to-mild, while, again, LG's and SA's performance was worse, pointing to a mild-to-severe impairment. In repetition, the three PwAs had similar performance, suggesting a medium level of impairment.

Table 2. Summary of PwAs' performance in the Aachen Aphasia Test.

Task	NN	LG	SA
Repetition	50	46	44
Sounds	28 (93%)	25 (83%)	29 (97%)
Monosyllabic words	25 (83%)	25 (83%)	29 (97%)
Foreign words	27 (90%)	22 (73%)	28 (93%)
Complex words	19 (63%)	20 (67%)	15 (50%)
Sentences	12 (40%)	13 (43%)	3 (10%)
Written Language	66	34	39
Reading aloud	26 (87%)	15 (50%)	22 (73%)
Composite to dictation	22 (73%)	12 (40%)	7 (23%)
Write to dictation	17 (57%)	NA	4 (13%)
Naming	57	62	43
Objects: simple words	24 (80%)	26 (87%)	21 (70%)
Colors: adjectives	23 (77%)	24 (80%)	21 (70%)
Objects: compound nouns	21 (70%)	22 (73%)	15 (50%)
Situations and actions	17 (57%)	17 (57%)	11 (37%)
Comprehension	83	56	59
Auditory word comprehension	30 (100%)	30 (100%)	20 (67%)
Auditory sentence comprehension	20 (67%)	20 (67%)	22 (73%)
Word reading comprehension	29 (97%)	20 (67%)	22 (73%)
Sentence reading comprehension	20 (67%)	14 (47%)	21 (70%)

Note. Results of the AAT subcomponents in bold are provided in terms of percentile ranks. Percentile ranks over 90 indicate no aphasia, ranks between 90 and 60 indicate mild aphasia, between 60 and 30 medium aphasia, and below 30 severe aphasia. Results of the single tasks are provided in terms of number of points obtained. In each task, a maximum of 30 points can be obtained; 3 points are assigned to correct responses and 0 points to incorrect responses, while 2 or 1 points can be assigned for intermediate cases, e.g. if the produced word or sentence had some degree of similarity to the stimulus.

We additionally designed an ad-hoc test to assess PwAs' performance with complex words, testing reading aloud, repetition, visual lexical decision, and auditory lexical decision. Items in the reading aloud and repetition tasks were matched for morphological complexity, length, and frequency; so were the items in the two lexical decision tasks (visual and auditory). Table 3 presents details about the materials of the test and its outcome. Overall, although the PwAs varied in the number of errors they produced, reading aloud complex words was severely impaired in all of them, and significantly more impaired than repetition. Considering that, for all PwAs, performance in the visual lexical decision task was comparably better, their impairment does not seem to be located in the morphological processes that are specifically tied to orthographic processing in the input modality[1]. A qualitative analysis of the errors produced in reading aloud revealed that four out of 13 errors (30.8%) made by NN were substitutions or omissions of affixes (e.g., *Vertreter* "representative": «vertreten» "represent"), one error was an insertion of an ending between two morphemes (*freundschaftlich* "friendly": «*freundeschaftlich» *friendsly), one error was possibly visual (*decken* "cover": «stecken» "insert"), one was a substitution with an unrelated word, and six were word fragments, omissions, or non-meaningful letter strings. In the case of LG, ten of 17 errors (58.8%) were affix substitutions, six were word fragments, omissions, or non-meaningful letter strings, and one was a substitution that may be classified as visual error. As for SA, of her 18 errors, nine (50%) were affix substitutions or omissions, one was a visual error, two were substitutions with unrelated words, and six were omissions or non-meaningful letter strings.

Table 3. Mean item properties (standard deviation in parenthesis) and summary of PwAs' performance in the ad-hoc preliminary test.

Task	Item Properties		Number of Correct Responses		
	Length (Letters)	Zipf Frequency	NN	LG	SA
Reading aloud (N=20)	9.85 (2.72)	3.28 (0.83)	7 (35%)	3 (15%)	2 (10%)
Repetition (N=20)	9.75 (2.71)	3.27 (1.11)	16 (80%)	11 (55%)	12 (60%)
Reading aloud vs. repetition			χ^2 = 8.286, *p* = .0040*	χ^2 = 7.033, *p* = .0080*	χ^2 = 10.989, *p* = .0009*
Visual lexical decision (N=35)			26 (74%)	25 (71%)	26 (74%)
Existing words (N=25)	9.32 (2.29)	3.06 (1.20)	19 (76%)	18 (72%)	20 (80%)
Non-words (N=10)	9.40 (2.46)	-	7 (70%)	7 (70%)	6 (60%)
Auditory lexical decision (N=35)			28 (80%)	25 (71%)	24 (69%)
Existing words (N=25)	9.36 (2.48)	3.20 (1.21)	19 (76%)	18 (72%)	17 (68%)
Non-words (N=10)	9.60 (2.67)	-	9 (90%)	7 (70%)	7 (70%)
Visual vs. auditory lexical decision			χ^2 = 0.324, *p* = .5692	χ^2 = 0, *p* = 1	χ^2 = 0.280, *p* = .5967

Note. Item types in the reading aloud and repetition tasks: 4 compounds (2 inflected), 3 prefixed derivations (1 inflected), 4 suffixed derivations (all inflected), 2 derivations with two affixes (two suffixes or prefix and suffix), 3 inflected words, 4 simple words (2-3 syllables). Item types in the visual and auditory lexical decision task: 25 existing words, of which 6 compounds (2 inflected), 3 suffixed derivations (all inflected), 2 prefixed derivations (1 inflected), 3 derivations with two affixes (prefix + suffix), 9 inflected words (2 irregular), 2 simple words (3-4 syllables); 10 non-existing words, of which 8 items created from existing words, deleting, adding, or substituting 1-2 letters from 2 simple words, 1 prefixed word, 1 suffixed word, 2 compound words, 2 inflected words; 1 illegal combination of stem with prefix; 1 illegal combination of stem with 2 suffixes.

A control group of eight participants without language or neurological impairments additionally took part in the main experimental task. The control group was comparable for age (mean 67.4, SD 3.8, range 62–70), gender (4 men, 4 women), and education background (four with university degree, four with vocational training education) to the three PwAs.

Materials

The experimental items were 60 simple words, 60 prefixed words, and 60 suffixed words. Each condition contained 20 adjectives, 20 nouns, and 20 verbs. All derived words consisted of one stem and one derivational morpheme; all verbs additionally contained the inflectional affix *-en*, which is the infinitival ending. Item characteristics are presented in Table 4. Following Sassenhagen and Alday (2016), matching information of the items across conditions is presented in terms of descriptive (mean, SD, range) rather than inferential statistics. Because suffixes tended to be longer than prefixes, we matched the items in the prefixed and suffixed condition for the length of their stems. All items were selected from a list of words that had been previously rated by German native speakers for imageability and semantic transparency, on a 1–7 scale (1 = lowest imageability/transparency), in two online surveys. Twenty-three subjects (19 women; mean age 33.96, SD 14.79) participated in the imageability survey, which included 369 simple and complex words, and twenty subjects (15 women; mean age 33.35, SD 9.97) participated in the transparency survey, which contained 321 complex words. Number of neighbors (Coltheart's count, absolute), as well as word-form and lemma frequency were extracted from the dlex database (Heister et al., 2011). We additionally computed affix frequency by extracting the number of lemmas beginning with the letter string corresponding to each prefix, as well as the number of lemmas ending with the letter string corresponding to each suffix, normalized by the number of types included in the corpus. Frequency is provided in zipf-scale (Heuven et al., 2014). Items in all conditions and, if applicable, their stems and affixes had similar frequency distributions (in both word-form and lemma frequency) as well as similar distributions in terms of number of neighbors, imageability, and transparency. Finally, items in the different conditions were also similar in terms of phonological complexity. Respectively, 22 simple items (36.7%), 24 prefixed items (40%), and 16 suffixed items (26.7%) contained complex onsets, while 11 simple items (18.3%), 23 prefixed items (38.3%), and 21 suffixed items (35%) contained complex codas. Only three items in each condition contained hiatuses.

Table 4. Stimuli properties (mean, SD, range) of the experimental task.

Property	Suffixed (N = 60)	Prefixed (N = 60)	Simple (N = 60)
Transparency	6.05 (0.64) 3.56 - 6.76	5.64 (1.01) 3.15 - 6.86	
Imageability	3.97 (1.26) 2.00 - 6.52	3.83 (1.14) 2.04 - 6.33	4.43 (1.23) 2.26 - 6.52
Affix Frequency	6.39 (0.42) 5.84-7.67	6.65 (0.40) 5.60-7.07	
Length (Letters)	9.00 (1.73) 6 - 13	8.32 (1.57) 6 - 12	7.23 (1.16) 6 - 10
Stem Length (Letters)	5.62 (1.37) 3 - 9	5.60 (1.33) 3 - 9	
Word-Form Frequency	3.17 (0.58) 1.69 - 4.71	2.94 (0.65) 1.21 - 4.71	3.45 (0.53) 1.51 - 4.23
Stem Word-Form Frequency	4.37 (0.64) 2.98 - 5.60	4.38 (0.61) 2.92 - 5.37	
Lemma Frequency	3.48 (0.52) 2.31 - 4.79	3.31 (0.63) 1.61 - 4.78	3.90 (0.44) 2.48 - 4.69
Stem Lemma Frequency	4.61 (0.61) 2.99 - 5.83	4.78 (0.60) 3.53 - 5.85	
Number of Neighbors	2.27 (2.17) 0 - 9	1.95 (1.31) 0 - 5	6.43 (5.34) 0 - 25
Stem Number of Neighbors	18.15 (16.21) 0 - 76	13.85 (10.17) 1 - 44	

All materials were tested twice, in two separate sessions, with an interval of at least one week between the two sessions, so that, in total, each subject read 120 simple words, 120 prefixed words, and 120 suffixed words. Complete lists of the experimental items and of the affixes used in the experiment are provided in the Appendix Tables A1, A2, A3, and A4.

Procedure

The experimental sessions took place at the participants' homes, under quiet conditions. The experiment was run on a Macintosh Air 13″, using the software PsychoPy (Peirce, 2007), version 1.82.00. Each stimulus was presented in isolation, in lowercase letters (the first letter being capitalized in the case of nouns, as by default in German), in the middle of a computer screen. Participants were instructed to read the word silently and press the space bar when they had finished reading the word. Immediately after pressing the space bar or after a timeout (7 s), a countdown automatically appeared on the screen for 5 s. This was followed by a production cue (an exclamation mark). When the production cue appeared, participants were expected to produce the word that they had just read. A maximum of 4 s were available for each individual response, after which the next target word appeared automatically. Delayed reading was preferred over immediate reading to ensure that speakers had enough time to pre-process the target word and to reduce effects of item properties (e.g., Ferrand, 2000; Sulpizio et al., 2015). All responses were recorded using an external microphone and automatically stored locally by the experimental software. A total of 240 items were presented for reading aloud, 180 of which were experimental items and 60 were fillers. All items were distributed over four blocks. Within each block, items were presented in a randomized order. Each block was followed by a break. All participants saw the four blocks in a different order and they were tested with the reversed order of blocks in the second experimental session.

The study was approved by the ethics committee of the University of Potsdam (application number 32/2016). All participants received remuneration for their participation in the study. All participants signed an informed consent prior to their participation, in accordance with the Declaration of Helsinki.

Data Analysis

We performed separate analyses for each of the three PwAs. For all analyses, we used binomial logistic regression models, as computed with generalized linear mixed effect models using the package lme4 (Bates et al., 2015) in the software R (version 3.6.2; R Core Team, 2018).

For the analysis testing the effect of Condition on error rates, responses were classified as "error" or "correct," respectively, coded with 1 and 0 for the logistic regressions. Condition had three levels: simple, prefixed, and suffixed; "simple" was set as baseline, so that the models compared the performance with, respectively, prefixed and suffixed words to performance with simple words. We then conducted analyses on the types of errors produced with prefixed and suffixed words by each PwA, specifically focusing on affix errors and errors on stems. In line with previous literature (e.g., Rastle et al., 2006), we classified as "affix error" any error in which the stem was preserved while the affix was not produced correctly, i.e., it was either omitted (*unsauber* [un-][sauber] "not clean": «sauber» "clean", NN), substituted (*machtlos* [macht][-los] "powerless": «machtvoll» [macht][-voll] "powerful", SA), or substituted with non-lexical letter strings (neologisms; *erdenken* "think up" [er-][denken]: «*kaldenken», NN). Errors on stems were errors in which the affix was preserved but the stem was either substituted with another existing stem (e.g., *drahtlos* [draht][-los] "wireless": «gnadenlos» [gnaden][-los] "merciless", SA) or with a neologism, which was generally phonologically similar to the stem (e.g., ***unreif*** [un-][reif] "immature": «*ungleif», LG). For each PwA, we fitted two binomial logistic regression models having as dependent variable, respectively, the occurrence of affix errors and the occurrence of errors on stems, coded with 1, as compared to any other output, coded with 0 (see Marelli et al., 2013). All models included Condition as fixed effect, with two levels (prefixed, suffixed; baseline = prefixed).

Other error types included whole-word substitutions with other complex words (e.g., ***Urpflanze*** [ur-][pflanze] "primordial plant": «Unwetter» [un-][wetter] "storm", NN), with simple words (e.g., ***kraftlos*** [kraft][-los] "powerless": «frei» "free", SA), or with neologisms (e.g., ***unklar*** [un-][klar] "unclear": «*urklei», NN), whole-word omissions, affix insertions (e.g., ***unwichtig*** [un-][wichtig] "unimportant" [un-][wichtig][-keit]: «Unwichtigkeit» "unimportance", LG; ***Pflanze*** "plant": ≪Pflanzen≫ [Pflanze][-n] "plants", NN), and letter deletions in the ***-en*** infinitival verb endings (e.g., ***leugnen*** "(to) deny": «leugne» "(I) deny"; note the three conditions contained the same number of verbs). Immediate repairs were scored as correct, while long hesitations, interruptions after a word fragment, and null reactions were scored as whole-word omissions. With the main goal of not confounding articulatory difficulty with reading errors (especially in the case of NN, who had mild dysarthria), phonological errors were counted as correct responses if the distortion or insertion only involved one phoneme, thus allowing the stem or the affix to be clearly recognizable (see Marusch et al., 2012; Marusch et al., 2017). The few cases in which participants were disturbed by external factors or refused to complete the task due to tiredness were not included in the total count of items presented.

All models included random intercepts for items. Binomial logistic regression models allowed for additionally testing for inclusion of the following covariates: Session, to account for the fact that all items were tested twice; Trial Number, to account for training or fatigue effects throughout the experiment; and some relevant psycholinguistic variables (transparency, imageability, stem length, word-form and lemma frequency of full form and stem, affix frequency, neighbors of full form and stem). This way, any significant effect of Condition is controlled for (i.e., goes beyond) any effect of item characteristics or artifacts from the experimental setup, such as trial number and session (Sassenhagen and Alday, 2016). We first tested for inclusion of each covariate separately, and then of the relevant random slopes by items for all fixed factors. Covariates and random slopes were only added if they significantly improved the model fit, which we tested by comparing the simpler model to the more complex model via likelihood ratio chi-square tests (Baayen, 2008). For some of the models we fitted, the covariates did have a significant effect, while including random slopes never improved the model fit for any of the analyses. In the Results section, we report results concerning our main predictor (Condition) and the covariates that significantly improved the fit of the models.

RESULTS

The language-unimpaired subjects from the control group produced exclusively correct responses, except for one subject who omitted two prefixed items. Error rates and types of the three PwAs are summarized in Table 5.

Table 5. Summary of PwAs' error rates and types in the experimental task.

Errors	NN			LG			SA		
	simple	prefixed	suffixed	simple	prefixed	suffixed	simple	prefixed	suffixed
Types of errors									
Affix errors	-	23	10	-	11	11	-	25	4
(omissions; substitutions; neologisms)	-	(11; 6; 6)	(5; 5; 0)	-	(5; 6; 0)	(7; 3; 1)	-	(20; 5; 0)	(1; 2; 1)
Errors on stems	-	14	14	-	17	7	-	9	3
(substitutions; neologisms)	-	(8; 6)	(3; 11)	-	(10; 7)	(4; 3)	-	(7; 2)	(2; 1)
Substitutions with complex words	3	5	4	8	9	9	5	4	3
Substitutions with simple words	4	0	1	11	3	5	19	13	14
Neologisms	21	7	13	18	10	5	5	5	7
Omissions	10	17	17	15	3	18	38	44	50
Morpheme insertions	5	2	9	12	13	3	0	2	0
Letter deletions in verb endings	1	0	0	0	0	0	3	0	0
Total number of errors	44/119 37%	68/119 57%	68/116 59%	64/119 54%	66/117 56%	58/119 49%	70/117 60%	102/117 87%	81/116 70%

Note. Number of errors out of total number of trials for each participant and condition. The table does not report the cases in which insertions of morphemes occurred in addition to other errors: WE inserted additional morphemes to the end of words in two cases of prefix omissions, four cases of prefix substitutions, and one case of stem substitution. SA inserted morphemes to the end of words in three cases of prefix omissions.

NN produced more errors with both prefixed and suffixed words than with simple words; error rates were similar for prefixed and suffixed words. The effect of Condition on error rates was significant for both the comparison between prefixed and simple words (β = 0.9806, SE = 0.3412, z = 2.874, p = 0.0041) and that between suffixed and simple words (β = 1.0513, SE = 0.3457, z = 3.041, p = 0.0024). None of the covariates we tested for inclusion significantly improved the model fit. As for the types of errors produced, there were more affix errors with prefixed words than with suffixed words. The model testing the number of affix errors produced in the two types of derived words revealed a significant effect of Condition (β = -1.0943, SE = 0.4990, z = -2.193, p = 0.0283), confirming the difference between prefixed and suffixed words on the number of affix errors, as well as a significant effect of Stem Length (β = 0.5221, SE = 0.2374, z = 2.199, p = 0.0279) suggesting that affix errors additionally increased with increasing length of the stem. Affix errors with prefixed words were more often omissions than substitutions or neologisms. Errors on stems occurred in similar rates for prefixed and suffixed words. The best fit model testing errors on stems showed no evidence for a difference between the two conditions (β = 0.0456, SE = 0.5348, z = 0.085, p = 0.932). For this model, the model only including the effect of Condition without covariates did not converge; we thus fitted other models, additionally including each of the covariates, and took the model with the best fit. The best-fit model included the covariate Number of Neighbors, which showed no significant effect (β = -0.4011, SE = 0.3247, z = -1.235, p = 0.217).

As for LG, there was clearly no effect of Condition on his error rates, which were similar for simple, prefixed, and suffixed items (prefixed vs. simple: β = -0.2325 SE = 0.6447, z = -0.361, p = 0.7184; suffixed vs simple: β = -0.4758, SE = 0.6305, z = -0.755, p = 0.4504). Instead, the model revealed significant effects of Imageability (β = -0.7838, SE = 0.2705, z = -2.897, p = 0.0038), Word-Form Frequency (β = -2.3114, SE = 0.6696, z = -3.452, p = 0.0006), Lemma Frequency (β = 1.8336, SE = 0.6543, z = 2.802, p = 0.0051), and Session

(β = -0.3298, SE = 0.1554, z = -2.122, p = 0.0338). This suggests that errors increased with increasing lemma frequency, while they decreased with increasing word-form frequency and imageability, and that LG produced fewer errors in the second session. As for affix errors, they were produced in similar amounts for prefixed and suffixed words. The best-fit model showed that the effect of Condition (suffixed vs prefixed) was not significant (β = -0.0195, SE = 1.3757, z = -0.014, p = 0.9887), while there was a marginal effect of Trial Number (fewer affix errors with increasing trial number; β = -0.8669, SE = 0.4587, z = -1.890, p = 0.0588). Despite a numerical tendency for more errors on stems with prefixed than suffixed words, the model produced no evidence for a difference between the two conditions (β = -1.1813, SE = 1.3736, z = -0.860, p = 0.3898), and no other factor significantly improved the model fit.

Finally, SA produced more errors with prefixed words, followed by suffixed and simple items. The larger number of errors with prefixed than simple words turned out to be significant (β = 1.4584, SE = 0.3984, z = 3.660, p = 0.0003), while there was no significant difference between suffixed and simple items (β = 0.2999, SE = 0.3340, z = 0.898, p = 0.3693). The best fit model included significant effects of Imageability and Trial Number (respectively: β = -0.5629, SE = 0.1553, z = -3.624, p = 0.0003; β = 0.3547, SE = 0.1424, z = 2.490, p = 0.0128), signaling that error rates additionally decreased with increasing imageability and increased as the experiment proceeded. Because, for SA, we observed a larger number of errors with prefixed than suffixed words, we additionally changed the baseline of the factor Condition to “prefixed” in order to directly compare the two types of derived words. The effect of Condition for the comparison between prefixed and suffixed items was significant (β = -1.1585, SE = 0.3979, z = -2.911, p = 0.0036). SA produced significantly more affix errors with prefixed words than with suffixed words (β = -2.0554, SE = 0.5806, z = -3.540, p = 0.0004), and affix errors on prefixes were mostly omissions. Finally, there was no evidence for a difference between prefixed and suffixed words in terms of number errors on stems (β = -1.1029, SE = 1.6361, z = -0.674, p = 0.5002). Neither of the two latter models included additional significant covariates.

The prefixed and suffixed items in our experiment contained a range of different affixes with different meanings or functions. As observed by De Bleser and Bayer (1990), this may have a relevant impact on errors produced on affixes. With exploratory purposes, we built a subset of semantically homogenous items to check whether, once the meaning of the affix is additionally controlled for, the results on affix errors would numerically be in line with those found for the entire item set. This subset included 20 prefixed words containing the negative prefix ***un-*** (7 adjectives, 13 nouns) and 20 suffixed words containing the negative suffix *-los* (all adjectives), all tested twice. In line with the results we report for the whole set of items, SA and, to some extent, NN produced numerically more affix errors with prefixed than with suffixed words (NN: prefixed 3/40, 8% and suffixed 1/40, 2%; SA: prefixed 9/38, 24% and suffixed 2/38, 5%; LG: no affix errors).

Discussion

In the present study, we tested three individuals with agrammatic aphasia who, in a preliminary task, showed an impairment for reading aloud morphologically complex words. Our experiment involved reading aloud of simple, prefixed, and suffixed words. We focused on whether prefixed words were more impaired than suffixed words in terms of error rates, as well as on the likelihood of producing errors involving affixes and errors involving stems.

One participant, LG, showed results that are not in line with a profile of morphological impairment. Despite the large number of errors with complex words that

LG produced in the preliminary assessments, in the experimental task he produced a similar amount of errors in all conditions. Therefore, for LG, there is no evidence that complex words are more impaired than simple words. There are two possible explanations for why we did not observe an effect in the expected direction. In order to create sets of prefixed, suffixed, and simple items that were comparable for length, we included more non-Germanic words in the simple condition than in the prefixed and suffixed item sets. These words, despite being ordinary words of German, may contain infrequent sound clusters and do not take the standard stress pattern of German, which may make them harder to produce for speakers with language impairment. Hence, the lack of difference between complex words (prefixed and suffixed) and simple items may be due to increased error rates in the simple condition. Indeed, nearly half of the incorrect responses LG produced with simple words (31/64) involved non-Germanic items. Another possible explanation is that many of the items in the preliminary task contained inflectional suffixes, while the main experiment focused on derived words. This may indicate that LG is impaired for reading inflected words, but not derived words. The fact that LG produced a relatively small number of errors selectively affecting the affix, for both prefixed and suffixed words, also speaks against a morphological impairment, at least for derived words.

NN, instead, showed the typical profile of a morphological impairment, with a significant disadvantage for both prefixed and suffixed words as compared to simple words, and similar error rates with the two types of derived words. This is in line with previous studies testing both prefixed and suffixed words (e.g., Job and Sartori, 1984; Kay, 1988; Hamilton and Coslett, 2008), which, however, did not specifically test for differences between these two types of derivations. When we analyzed the types of errors produced with prefixed and suffixed words, we found that prefixes were more likely to be specifically impaired than suffixes. Instead, the number of errors affecting stems were similar in the two conditions.

Finally, SA had yet a different profile. Like NN, she produced significantly more errors with prefixed words than with simple words. In contrast, error rates with suffixed words did not differ from error rates with simple words. Instead, she produced significantly more errors with prefixed words than with suffixed words, suggesting that prefixed words were selectively impaired. Like NN, she also produced significantly more affix errors on prefixes than on suffixes. Errors on stems did not differ in the two conditions.

Let us now come to what we can specifically conclude about prefixed words. When we analyzed error rates, we found that both NN and LG produced similar numbers of errors with prefixed and suffixed words. Instead, for SA, we reported a selective impairment for prefixed words. This dissociation between prefixed and suffixed words can only be explained by positing that, at some level of processing, the relative position of affix and stem influences how prefixed and suffixed words are processed and retrieved. This is in line with previous results from psycholinguistic studies that have reported larger processing costs for prefixed as compared to suffixed words, which the authors explained in terms of more effortful access to the stem when this is in word-final position (Bergman et al., 1988; Colé et al., 1989; Beauvillain, 1996; Ferrari Bridgers and Kacinik, 2017). We therefore suggest that this can also extend to the retrieval of prefixed words in morphological impairment. Retrieving prefixed words would be more costly than retrieving suffixed words, causing larger error rates with prefixed words than with suffixed words. Note that SA seemed to be the participant with the most severe impairment, as reflected by the much larger number of errors she produced compared to the other participants. This may indicate that clear dissociations between prefixed and suffixed words can only be observed in cases of rather severe impairments.

Difficulty in accessing the stem of prefixed words, as compared to suffixed words, may also result in more errors on stems in the prefixed than in the suffixed condition. However, we reported similar numbers of errors on stems in prefixed and suffixed words for all PwAs. It is important to point out that in the present study, unlike in the study by Semenza et al. (2002), morphologically based errors produced with prefixed words involved affixes more often than stems (at least in NN and SA), which is in line with previous evidence on suffixed words (e.g., Rastle et al., 2006). The fact that morphological impairments of derived words generally affect affixes rather than stems implies that the numbers of errors involving stems that we can analyze is relatively small, making it difficult to detect differences between conditions. Future studies may try to address this issue by testing participants whose impairment affects more strongly stems than affixes (such as those reported by Semenza et al., 1990; Semenza et al., 2002).

When we analyzed the likelihood of producing affix errors, we found that NN and SA produced more affix errors with prefixes than with suffixes. Prefix errors in both NN and SA were mostly omissions. Figure 1 provides a graphical representation of the proportions of initial word segments (syllables or prefixes) and final word segments (syllables or suffixes) that were preserved. This should provide an idea about whether affix errors only result from an overall pattern of distortions of word beginnings or endings across all conditions. Importantly, the plot suggests that prefix errors in NN and SA cannot be explained by a general tendency of neglecting initial word segments.

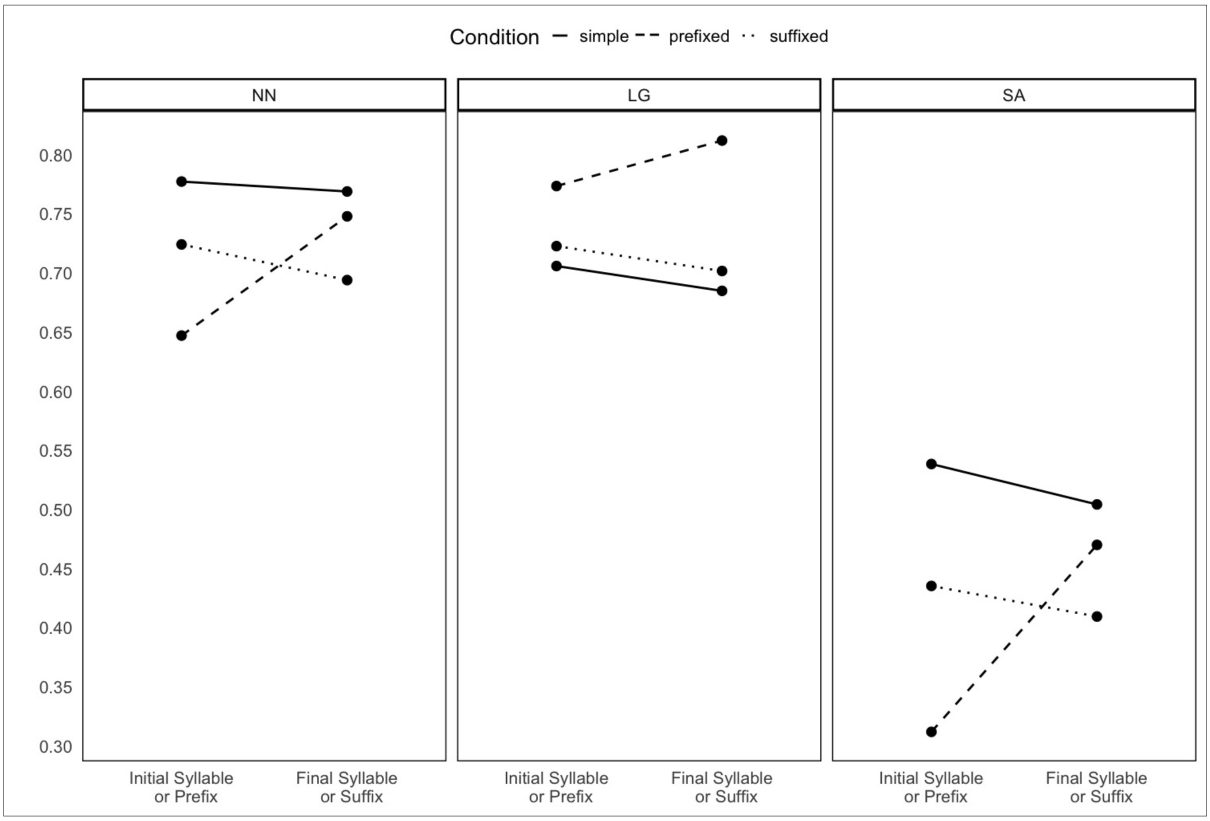

Figure 1. Mean accuracy in the production of initial syllables (or prefixes) and final syllables (or suffixes) in the three conditions, for each PwA across all trials. One point was assigned if the syllable (or affix) was produced correctly, 0.5 if the produced syllable (or affix) preserved at least one letter from the original syllable (or affix), and 0 if the produced syllable (or affix) was entirely different from the original one.

The larger likelihood of producing errors that affect prefixes compared to suffixes can be interpreted in terms of the different functions that prefixes and suffixes have in derived words, as discussed in some linguistic literature (e.g., Williams, 1981; Kastovsky, 2005): while prefixes generally do not express the grammatical properties of the derived word (i.e., they are not heads), suffixes generally do. We suggest that, in line with what we predicted, this makes prefixes generally more error-prone than suffixes. A question that remains open is whether the effect we report applies to prefixed words overall, or it is a bare headedness effect (see the literature on compounds, e.g., Jarema et al., 2010;

Semenza et al., 2011; Marelli et al., 2013). Future research may address this by directly comparing prefixed words containing head prefixes to the more common case of prefixed words in which the head is the stem. Access to head information may also be assessed by testing production of grammatical gender. This would clarify to what extent headedness plays a role in affix errors even in cases, like LG, for which the number of affix errors fails to reveal differences between prefixes and suffixes. A *post-hoc* descriptive analysis on a sub-set of semantically homogenous items seems to suggest that the effect we report would persist even when controlling for the semantic content of prefixes and suffixes. Further research may include larger, semantically homogeneous sub-sets of items, to test whether the numbers and types of affix errors with prefixes and suffixes vary depending on their meaning or function.

Finally, in line with previous research on morphological impairments (e.g., Funnell, 1987; Rastle et al., 2006), error rates and number of affix errors were, additionally, partly modulated by the stimuli characteristics. For LG and SA, errors decreased with increasing imageability. Additionally, in the case of LG, error rates also decreased with increasing word-form frequency; instead, increasing lemma frequency caused more errors, possibly because of larger error rates with verbs, which have larger lemma frequency. Finally, NN's rates of affix errors increased for words with longer stems. This highlights once again the importance of controlling for these variables when investigating morphological impairments, both by matching the items across conditions and by including the stimuli properties in the statistical models, so that the model outputs provide the effect of the experimental manipulation (in this case simple, prefixed, and suffixed words) controlled for any other relevant factor.

CONCLUSIONS

The present study investigated the errors produced with prefixed and suffixed words in three individuals with agrammatic aphasia. We report differences between prefixed and suffixed words with regard to error rates in one participant (SA) and with regard to affix errors in two participants (NN and SA). The selective impairment for prefixed words we report for SA makes the present study the first reporting a dissociation between prefixed and suffixed derived words, which had been, until now, never investigated in the literature on morphological impairments. This dissociation can only be accounted for by postulating processing differences between prefixed and suffixed words. In line with previous psycholinguistic studies, we claim that the word-final position of the stem in prefixed words makes their retrieval more costly, and thus prefixed words more difficult to retrieve than suffixed words. Furthermore, in two of the participants (NN and SA) we reported a difference between prefixes and suffixes concerning the likelihood of producing affix errors, with prefixes being more impaired than suffixes. We explained this difference in terms of the different functions of prefixes and suffixes.

Because derivation by prefixation in German is much more widespread than in other Indo-European languages (Smolka et al., 2014; Günther et al., 2019), we believe that our results do not have to do with relative frequency of use of derivational prefixes and suffixes in a specific language, but rather with universal aspects of how prefixed and suffixed words are processed. A question that remains open is at which specific stage of the reading-aloud processes differences between prefixed and suffixed words become relevant. Future research may shed light on this aspect by assessing, in more thorough preliminary testing of each participant, the specific locus of their morphological impairment.

NOTES

1. Note, however, that performance in the visual and auditory lexical decision tasks, despite being well above chance, was overall relatively poor as compared to what would be expected from the corresponding sub-tests on written and auditory word comprehension in the AAT (at least for NN, and, to some extent, LG). This may be due to the fact that the items used in the task were particularly complex, especially because many of them contained inflectional affixes.

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APPENDIX

Experimental items

Table A1. Simple items.

Item	Class	English Equivalent	Item	Class	English Equivalent
anonym	Adj	anonymous	locker	Adj	relaxed
Aprikose	N	apricot	löschen	V	clear
arrogant	Adj	arrogant	Marmelade	N	jam
bitter	Adj	bitter	Mission	N	mission
bizarr	Adj	bizarre	munter	Adj	lively
brennen	V	burn	passiv	Adj	passive
dezent	Adj	discreet	perfekt	Adj	perfect
düster	Adj	gloomy	Pfeffer	N	pepper
elegant	Adj	elegant	Pflanze	N	plant
flechten	V	weave	Pflaume	N	plum
fliehen	V	flee	prahlen	V	brag
fließen	V	flow	rauschen	V	sough
forschen	V	research	Rebell	N	rebel
gleiten	V	slide	Referendum	N	referendum
glimmen	V	glow	Region	N	region
grotesk	Adj	grotesque	Restaurant	N	restaurant
heiser	Adj	hoarse	Rezept	N	recipe
heiter	Adj	bright	rutschen	V	slip
immens	Adj	enormous	schalten	V	switch
intakt	Adj	intact	Schenkel	N	leg
Joghurt	N	yogurt	Schinken	N	ham
kaputt	Adj	broken	schmecken	V	taste
klappen	V	fold	Schokolade	N	chocolate
Kloster	N	monastery	schrumpfen	V	shrink
Kognak	N	cognac	schwinden	V	dwindle
Kolonie	N	colony	schwören	V	swear
Konvent	N	convention	simpel	Adj	simple
kreischen	V	screech	spontan	Adj	spontaneous
lauschen	V	listen	trocken	Adj	dry
leugnen	V	deny	Zwetsche	N	plum

Table A2. Prefixed items.

Item	Class	English Equivalent	Item	Class	English Equivalent
Desillusion	N	disillusion	unklar	Adj	unclear
Desinteresse	N	lack of interest	unklug	Adj	unwise
Disharmonie	N	disharmony	Unkraut	N	weed
entblößen	V	uncover	Unlust	N	listlessness
entfremden	V	alienate	Unmensch	N	brute
entgleisen	V	be derailed	unmodern	Adj	olde-fashioned
enthaupten	V	behead	unrecht	Adj	wrong
entkräften	V	weaken	unreif	Adj	immature
entladen	V	unload	unsanft	Adj	rough
entspannen	V	relax	unsauber	Adj	unclean
erblinden	V	go blind	unschön	Adj	ugly
erdenken	V	think up	Unschuld	N	innocence
erfinden	V	invent	unseriös	Adj	untrustworthy
erheitern	V	amuse	Unwetter	N	storm
erhitzen	V	heat	unwichtig	Adj	unimportant
Erzbischof	N	archbishop	Urenkel	N	great-grandson
Erzengel	N	archangel	Urkraft	N	elemental force
Erzfeind	N	archenemy	Urmensch	N	caveman
illegal	Adj	illegal	Urpflanze	N	primordial plant
inaktiv	Adj	inactive	Urtext	N	original text
indiskret	Adj	indiscreet	Urvolk	N	primitive man
inexakt	Adj	inexact	Urwald	N	jungle
inkomplett	Adj	incomplete	veralten	V	become outdated
instabil	Adj	unstable	verarbeiten	V	process
irreal	Adj	unreal	verarmen	V	become poor
unbequem	Adj	uncomfortable	verbrennen	V	burn
unfertig	Adj	unfinished	verlernen	V	unlearn
Unfrieden	N	discord	verpflichten	V	commit
ungleich	Adj	unequal	verschlafen	V	sleep through
Unglück	N	bad luck	verspäten	V	delay

Table A3. Suffixed items.

Item	Class	English Equivalent	Item	Class	English Equivalent
analysieren	V	analyze	Musiker	N	musician
Apotheker	N	pharmacist	nächtigen	V	spend the night
Autorschaft	N	authorship	namenlos	Adj	nameless
Bruderschaft	N	brotherhood	parteilos	Adj	independent
drahtlos	Adj	wireless	Pensionär	N	pensioner
elternlos	Adj	parentless	Pförtner	N	usher
Erbschaft	N	heritage	präzisieren	V	clarify
farblos	Adj	colorless	probieren	V	try
Feindschaft	N	enmity	problemlos	Adj	unproblematic
festigen	V	consolidate	protestieren	V	protest
folgern	V	conclude	respektieren	V	respect
fristlos	Adj	without notice	respektlos	Adj	disrespectful
Gärtner	N	gardener	sänftigen	V	soften
Glöckner	N	bell ringer	sättigen	V	saturate
gnadenlos	Adj	merciless	schädigen	V	damage
gottlos	Adj	godless	schamlos	Adj	shameless
heimatlos	Adj	homeless	schildern	V	describe
Herrschaft	N	control	schlittern	V	slide
huldigen	V	pay homage to	skrupellos	Adj	unscrupulous
interessieren	V	interest	Sportler	N	athlete
kopieren	V	copy	Städter	N	townsman
kraftlos	Adj	powerless	stimmlos	Adj	unvoiced
kreuzigen	V	crucify	telefonieren	V	phone
Kundschaft	N	clientele	Töpfer	N	potter
legitimieren	V	legitimize	tonlos	Adj	toneless
machtlos	Adj	powerless	Vaterschaft	N	fatherhood
Mediziner	N	doctor	wertlos	Adj	worthless
Milliardär	N	billionaire	ziellos	Adj	aimless
Millionär	N	millionaire	zinslos	Adj	without interest
modernisieren	V	modernize	Zöllner	N	customs officer

Table A4. List of affixes.

Affix	N. of items	Meaning/ Function	Example
<u>Prefixes</u>			
des-/dis-	3	negation	*Interesse* 'interest' *Desinteresse* 'indifference'
erz-	3	'arch-'	*Bischof* 'bishop' *Erzbischof* 'archbischop'
un-	20	negation	*schön* 'beautiful' *unschön* 'not beautiful'
ur-	7	ancient, original	*Mensch* 'human being' *Urmensch* 'caveman'
in-/il-/ir-	7	negation	*legal* 'legal' *illegal* 'illegal'
ent-	7	privative	*laden* 'load' *entladen* 'unload'
er-	5	resultative	finden 'find' erfinden 'invent'
ver-	8	privative / resultative	lernen 'learn' verlernen 'unlearn' alt 'old' veralten 'become outdated'
<u>Suffixes</u>			
-er/-ler/-ner	10	agentive	*Musik* 'music' *Musiker* 'musician'
-är	3	agentive	*Million* 'million' *Millionär* 'millionaire'
-schaft	7	collective / description of a status	*Autor* 'author' *Autorschaft* 'authorship'
-los	20	negation	*kraft* 'power' *kraftlos* 'powerless'
-ieren	10	action from noun	*Telefon* 'phone (N)' *telefonieren* 'phone (V)'
-igen	7	resultative	*fest* 'firm' *festigen* 'consolidate'
-ern	3	action from noun	*Schild* 'sign' *schildern* 'describe/outline'

6. Publication IV

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Morphological errors in acquired dyslexia: The case of prefixed words

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ABSTRACT

Reading aloud morphologically complex words has been consistently found to be impaired in acquired dyslexia. Individuals with acquired dyslexia generally make more errors with complex than with simple words, and they produce so-called 'morphological errors', i.e. errors that reflect the morphological structure of the complex word. These findings have been taken as evidence that complex words are decomposed into their constituents instead of being treated as whole units. However, most research has focused on suffixed words (*payment* [pay][ment]), and much less is known on how prefixed words (*prepay* [pre][pay]) are affected in acquired dyslexia. Prefixation is much less widespread than suffixation in the world's languages. This has been explained in terms of processing and learnability disadvantages for prefixed words, which may in turn have consequences on how these are affected in language loss. In the present study, we describe three experiments involving a German adult with acquired phonological dyslexia. Our findings show that his reading of prefixed words is more impaired than the reading of simple words, and that his morphological errors with prefixed words can be dissociated from visual or semantic errors. We additionally provide evidence for a dissociation in how prefixes and suffixes are impaired.

Keywords: complex words; prefixes; embedded stems; phonological dyslexia; morphological decomposition; reading aloud.

INTRODUCTION

In recent years, a large number of studies have investigated how morphologically complex words, i.e. words composed of several constituents (such as *warehouse* [ware][house] or *buyer* [buy][er]), are stored and processed in the human mind and brain from different angles and using different experimental techniques and measures (for reviews, see Amenta & Crepaldi, 2012; Leminen, Smolka, Duñabeitia, & Pliatsikas, 2019; Semenza & Mondini, 2015). One line of research has tested how complex words are impaired in acquired language disorders, with the idea that this can provide insight about how complex words are represented in the unimpaired language system. A crucial advantage of experimental research with acquired language disorders is that differences between types of linguistic stimuli (e.g. between inflected and derived words such as *buys* and *buyer*) are observable even in relatively simple and ecological tasks, while, in psycholinguistic experiments with language-unimpaired adults, effects tend to be detectable only under rather artificial experimental conditions.

Particularly relevant for the study of morphology in language impairments are deep and phonological dyslexia (e.g. Luzzatti, Mondini, & Semenza, 2001; Rastle, Tyler, & Marslen-Wilson, 2006), as they systematically present with impaired reading aloud of morphologically complex words (but note that disorders of morphology, for different modalities and tasks, have additionally been reported for other language or neuropsychological disorders; e.g. Jargon aphasia: Semenza, Butterworth, Panzeri, & Ferreri, 1990; neglect: Semenza et al., 2011; Marelli, Aggujaro, Molteni, & Luzzatti, 2013; semantic dementia: Auclair-Ouellet, Fossard, Laforce, Bier, & Macoir, 2017). In deep dyslexia, reading aloud of function words, low imageability words, and non-words is impaired. Reading output is characterized by the production of semantic errors, i.e. words similar in meaning to the target words but with different phonological or orthographic form (e.g. *wood* → «tree»), and visual errors, i.e. words that are orthographically similar to the targets but unrelated in meaning (e.g. *brothel* → «brother»). Phonological dyslexia has similar symptoms to deep dyslexia, except that semantic errors do not occur (Coltheart, 1980; Funnell, 2000; Luzzatti, 2008; Patterson & Ralph, 1999). As for reading aloud of complex words, both types of dyslexia are characterized by a disadvantage for reading complex words compared to equally long simple words, and by the production of so-called 'morphological errors' particularly affecting affixes. These are generally affix omissions, e.g. *playful* → «play», or substitutions, e.g. *playful* → «player» (Funnell, 2000; Patterson, 1980; Semenza & Mondini, 2015).

The impairment of complex words in acquired dyslexias has been largely investigated in previous studies, especially with regard to suffixed words. These have focused on whether morphological errors produced with suffixed words (e.g. *player* [play][er]) are genuinely morphological, i.e. if they are dissociable from errors found with pseudo-suffixed words (e.g. *corner* [corn][er]) and/or with words containing embedded stems (e.g. *cashew* [cash]). On the one hand, Funnell (1987) claimed that morphological errors occur equally often with suffixed and pseudo-suffixed words once imageability and frequency of the full forms and of their stems are taken into account, thus concluding that morphological errors are just instances of visual or semantic errors (see also Badecker & Caramazza, 1987). On the other, evidence for genuinely morphological errors was reported in at least four later studies. Kay (1988) and Castles, Coltheart, Savage, Bates, and Reid (1996), using the items from Funnell's (1987) study, found more morphological errors with complex than pseudo-complex words. Similar findings were reported by Druks and Froud (2002) and Hamilton and Coslett (2008). Rastle et al. (2006) provided a quite thorough investigation on this question. They found that the numbers and types of morphological errors differed for suffixed words compared to both pseudo-complex words and words with embedded stems (with no difference between the latter two conditions), all items being matched for stem and full-form frequency and imageability. Critically, the authors also report that, while stem imageability also yielded a significant effect on the number of morphological errors, the latter occurred over and above any effect of imageability and frequency.

When it comes to the impairment of prefixed words in acquired dyslexia, instead, research has been much less systematic, and results are more mixed. Prefixed words have been mostly investigated as an additional set of items among various experiments, with few items per condition and no clear theory-driven predictions on how prefixed words should be impaired. Castles et al. (1996) found no difference between prefixed words and pseudo-prefixed words (e.g. *repeat* [re-][peat]) in terms of error rates, and no clear evidence of morphological errors (only one morphological error was produced). Instead, Hamilton and Coslett (2008), Job and Sartori (1984), and Kay (1988) found more morphological errors with prefixed than pseudo-prefixed words. However, Hamilton and Coslett (2008), Job and Sartori (1984) and Castles et al. (1996) did not control for stem imageability, which is a crucial limitation, given how strongly this predicts the occurrence of seemingly morphological errors (Funnell, 1987; but also Rastle et al., 2006). Stem imageability was controlled for in the study by Kay (1988), but imageability of the full forms was not matched across conditions. The only study specifically focusing on prefixation (Semenza, Girelli, Spacal, Kobal, & Mesec, 2002) reports an advantage for simple words compared to prefixed words, but no comparison of errors with prefixed and pseudo-prefixed words (e.g. *repeat* [re][peat]) or words with word-final embeddings (e.g. *suspend* [spend]). Finally, none of these studies compared the types of errors occurring with prefixes to the much more largely described case of errors occurring with suffixes, which would provide a more complete characterization of the impairment, possibly allowing for relevant conclusions about whether prefixes and suffixes words are affected differently in language loss.

Across the world's languages, the use of prefixes is less widespread than the use of suffixes (Greenberg, 1963). The cross-linguistic preference for suffixation has been explained in terms of mechanisms underlying the processing and learning of complex words. According to the processing account, suffixation would be favored because it is easier to process a complex word when its stem, which is the semantically most relevant component, occurs word-initially, i.e. in the portion of the word that is most salient for lexical access (Cutler, Hawkins, & Gilligan, 1985). Similarly, the learnability account postulates that suffixation would be preferred because learning the properties of the stem, which are encoded by the affix, is easier when the affix follows the stem (Ramscar, 2013; St. Clair, Monaghan, & Ramscar, 2009). Psycholinguistic studies on language unimpaired adults have shown that prefixed words are decomposed into their morphological constituents during processing, similarly to suffixed words (e.g. Diependaele, Sandra, & Grainger, 2009; Kazanina, 2011). However, it has also been suggested that decomposition may still be delayed in the case of prefixed words, which has been mostly explained in terms of larger processing costs for prefixed words because of the word-final position of the stem (Beauvillain, 1996; Bergman, Hudson, & Eling, 1988; Colé, Beauvillain, & Segui, 1989; Ferrari Bridgers & Kacinik, 2017; Kim, Wang, &

Taft, 2015), hence along the lines of the account by Cutler et al. (1985). Furthermore, language acquisition studies have shown earlier and easier acquisition of suffixes compared to prefixes (Kuczaj, 1979; Slobin, 1973), and psycholinguistic studies on children have shown that effects of morphological decomposition during reading emerge earlier in language development for suffixed than for prefixed words (Hasenäcker, Schröter, & Schroeder, 2017), which is in line with the predictions of the learnability account.

The cross-linguistic preference for suffixation, as well as the processing and learnability costs associated to prefixed words, may not only impact language processing and acquisition, but also how prefixed words are impaired in morphological disorders. However, the literature on acquired dyslexia lacks a systematic investigation of morphological errors in the case of prefixed words, which was the aim of the present study.

THE PRESENT STUDY

In the present study, we investigated morphological errors in reading aloud prefixed derived words in NN, a German individual with agrammatic aphasia and phonological dyslexia. In Experiment 1, we compared NN's performance with prefixed words and matched simple words, testing whether we would find a disadvantage for prefixed compared to simple words. In Experiment 2, we investigated whether morphological errors in prefixed words can be distinguished from visual errors. We compared errors with prefixed words to errors with simple words containing word-final embedded stems (e.g. *Gazelle* 'gazelle' [*Zelle* 'cell']), which we will refer to as the 'final embedding' condition[1]. Errors were analyzed in terms of error rates, number of affix errors, and types of affix errors (analogously to Rastle et al., 2006). Experiment 2 additionally included a suffixed and an 'initial embedding' condition (e.g. *Notiz* 'note' [*Not* 'need, necessity']). These were included with the aim of replicating previous evidence for genuinely morphological errors with suffixed words (e.g. Rastle et al., 2006) and additionally comparing the types of affix errors produced with prefixed words and suffixed words. In Experiment 3, we tested three-morphemic prefixed words ending with a suffix (e.g. *vertauschbar* [ver][tausch][bar] 'exchangeable') and three-syllabic simple words. We compared the error rates in simple and prefixed words testing again for an advantage of simple over complex words, and we looked at the types of errors produced with prefixes as opposed to suffixes appearing within the same word.

If, as suggested by previous psycholinguistic literature (Diependaele et al., 2009; Kazanina, 2011), prefixed derived words are decomposed during processing, then these should be impaired in acquired morphological disorders such as phonological dyslexia. Hence, in Experiment 1 and 3, we expected to observe more errors with prefixed than simple items, replicating previous results with prefixed words (Semenza et al., 2002), as well as with compound words and suffixed inflected and derived words (e.g. Luzzatti et al., 2001; Mondini, Arcara, & Semenza, 2012). As they are believed to reflect morphological decomposition, errors with prefixed words should also be truly morphological in nature. Hence, in Experiment 2, we expected to find more and qualitatively different morphological errors with prefixed words than with final embedding items, extending previous findings on suffixed words to prefixed words. Because word endings tend to be more impaired than word beginnings, the production of affix errors in suffixed words may be confounded with a more general neglect of word endings (Castles et al., 1996; Shallice & Warrington, 1975). Finding that morphological errors are dissociable from visual errors even with prefixed words, where such confound is at least reduced, would thus strengthen the evidence for the genuinely morphological nature of such errors. Finally, as regards the types of errors produced with prefixes, based on the cross-linguistic suffixing preference, we expected prefixes to be less retained than suffixes, thus leading to larger number of errors with prefixes, possibly omissions. Note however that, because decomposition of prefixed words may be more costly or delayed (Beauvillain, 1996; Bergman, Hudson, & Eling, 1988; Colé, Beauvillain, & Segui, 1989; Cutler et al., 1985; Ferrari Bridgers & Kacinik, 2017; Kim, Wang, & Taft, 2015), we may alternatively be unable to observe effects of morphological decomposition in the impairment of prefixed words.

Case Report

NN is a left-handed German man with university-level education. At the time of the first testing session, he was 64 years old and had suffered right-hemisphere stroke 23 years and 7 months earlier. NN's spontaneous speech is extremely simplified, with short sentences mostly lacking verbs or verbal inflection and function words, and with simple syntax (see Appendix A). He often relies on non-verbal communication, such as gestures or facial expressions. His oral comprehension, at least with simple sentences, is good. Prior to his participation in the present study, NN's linguistic abilities were assessed by means of the *Aachener Aphasie Test* (AAT; Huber, Poeck, Weniger, & Willmes, 1983) and the *Lexikon Modellorientiert 2.0* ('lexicon model-based', LEMO 2.0; De Bleser, Cholewa, Stadie, & Tabatabaie, 2004), based on which he was classified as having Broca's aphasia. Table 1 summarizes the results from these two assessments for the following sub-tests: discrimination of neologism pairs, lexical decision, repetition, reading aloud, writing, comprehension, and naming.

Table 1. Summary of NN's performance in the standardized language assessment tasks.

Task	AAT	LEMO
Discrimination of Neologism Pairs		Oral: 71/72 (99%)
Lexical Decision		Visual: 78/80 (98%)
Repetition	Sounds: 28/30 (93%) Monosyllabic words: 25/30 (83%) Foreign words: 27/30 (90%) Complex words: 19/30 (63%) Sentences: 12/30 (40%)	Neologisms:32/40 (80%)
Reading Aloud	Words/sentences: 26/30 (87%)	Regular/irreg. words: 51/60 (85%) Neologisms: 0/40 (0%)
Writing	Composing words: 22/30 (73%) Words/sentences: 17/30 (57%)	Neologisms: 0/40 (0%)
Comprehension/ Picture matching	Oral (words): 30/30 (100%) Oral (sentences): 20/30 (67%) Visual (words): 29/30 (97%) Visual (sentences): 20/30 (67%)	Oral (words): 19/20 (95%) Visual (words): 20/20 (100%)
Naming	Objects (simple words): 24/30 (80%) Colors (adjectives): 23/30 (77%) Objects (compounds): 21/30 (70%) Situations/actions: 17/30 (57%)	Oral: 20/20 (100%) Written: 9/20 (45%)

Note. Results were retrieved from the database of individuals with aphasia of the Linguistics Department, University of Potsdam.

NN additionally participated in an ad-hoc preliminary assessment specifically designed to test his performance with morphologically complex words. This included a visual and an oral task. In the visual task, a word or non-word was presented on a computer screen. NN was instructed to perform a lexical decision on the target word, and then read it aloud. Similarly, in the oral task, NN had to perform a lexical decision on an aurally presented word or non-word, and then repeat it. Both tasks included 60 existing words (20 simple and 40 complex words, including prefixed and suffixed words, and words with more than one affix) and 60 non-existing words, which were created by changing one letter from the existing words of the other task. NN's performance is summarized in Table 2.

Table 2. Summary of NN's correct responses in the ad-hoc preliminary assessment.

Item Type	Visual Lexical Decision	Oral Lexical Decision	Reading	Repetition
Words	50/60 (83%)	56/60 (93%)	32/60 (53%)	50/60 (83%)
Simple Words	16/20 (80%)	18/20 (90%)	14/20 (70%)	18/20 (90%)
Complex Words	34/40 (85%)	38/40 (95%)	18/40 (45%)	32/40 (80%)
Non-Words	50/60 (83%)	55/60 (92%)	8/60 (13%)	26/60 (43%)

Results from the pre-test were analyzed by means of chi-squared tests. In word trials, performance in reading aloud was worse than in visual lexical decision (53% vs. 83%, $\chi = 12.478$, $p < .001$). Furthermore, reading was also poorer than repetition (53% vs. 83%, $\chi = 12.478$, $p < .001$). When it comes to non-existing words, there was a significant disadvantage for producing non-words compared to real words in both reading aloud

(13% vs. 53%, $\chi = 21.6$, $p < .00001$) and repetition (43% vs. 83%, $\chi = 20.67$, $p < .00001$), but reading non-words was significantly more affected than repetition (13% vs. 43%, $\chi = 13.297$, $p < .001$). Finally, NN showed a numerical advantage for reading aloud simple words over complex words, yet this difference was only marginally significant (70% vs. 45%, $\chi = 3.348$, $p = .067$). Concerning the types of errors, out of the 28 errors that NN produced when reading existing words (22 with complex words and 6 with simple words), 16 were morphological and one was visual, but there were no semantic errors. Similarly, NN never produced semantic errors when reading non-words. Overall, the preliminary assessments point at a disorder that affects reading aloud more strongly than production overall and that does not originate from impaired visual recognition of the linguistic stimuli. The production of morphologically-based errors, as well as the large number of errors with morphologically complex words, are suggestive of a morphological impairment. All together, the characteristics of NN's impairment, also considering his inability to read non-existing words and the lack of semantic errors, point at a profile of phonological dyslexia.

METHODS OVERVIEW

For all the three experiments reported below, we extracted the frequency values (normalized per million) of the experimental items from the database dlexDB (www.dlex.db.de; Heister et al., 2011). The experimental materials of each experiment are described in details in the corresponding Materials section. Following Sassenhagen and Alday (2016), information about matching across conditions is reported in terms of descriptive rather than inferential statistics, and potential effects of the stimuli characteristics are accounted for in the statistical models (see Data Analysis). Complete lists of the experimental items are provided in Appendix B. All experiments took place in a quiet room in NN's apartment. The experiment was run using the experimental software PsychoPy, version 1.82.01 (Peirce, 2007). In all three experiments, NN was instructed to read aloud a series of words that were displayed on a computer screen for 800 ms, followed by a blank screen. The maximum time allowed for reading aloud was 3,000 ms. Trials were presented in a pseudo-randomized order, with items of the same condition never occurring one after each other. NN's responses were coded online by the experimenter and additionally recorded by an external audio-recorder. NN was tested twice on the same stimuli, in two different sessions. In the second session, items were presented in the reversed order.

The study was approved by the ethics committee of the University of Potsdam (application number 32/2016). NN signed an informed consent prior to his participation.

Data Analysis

All responses were first coded as 'correct response' or 'error'. Similarly to previous studies (e.g. Funnell, 1987; Rastle et al., 2006), we then identified all morphological errors in which the stem is spared and the affix (or the word beginning/endings, in the embedding conditions) is omitted or substituted, which we labeled 'affix errors', as opposed to 'other errors'. The latter included all other types of errors as well as null reactions and timeouts. Among affix errors, we distinguished between affix omissions, substitutions, or neologisms, i.e. distortions of the affix resulting in non-lexical strings. Immediate repairs and hesitations were coded as correct responses. Responses were coded as correct in case the words produced or their (embedded) stems contained a phonological distortion or an omission of a single phoneme, and thus they were clearly recognizable (see Marusch, Jäger, Burchert, & Nickels, 2017; Marusch, von der Malsburg, Bastiaanse, & Burchert, 2012). When items contained the infinitive verbal ending (*-en*), which was sometimes the case in Experiment 1 and 2, errors involving the verbal ending were not counted, i.e. the answer was considered correct, provided that the rest of the word was produced correctly (e.g. *begleiten* '(to) accompany' → «begleite» '(I) accompany' or «Begleiter» 'companion').

All analyses were performed using the software 'R', version 3.3.2 (R Development Core Team, 2012). Data from all experiments were analyzed with mixed-effects binary logistic regressions by means of the bglmer function from the package 'blme' (Chung, Rabe-Hesketh, Dorie, Gelman, & Liu, 2013), which extends the package 'lme4' (Bates, Mächler, Bolker, & Walker, 2015), and using the bobyqa optimizer (Powell, 2009). To deal with floor effects in some of the conditions, we added a weak prior to the fixed-effect parameters of all models (following Abrahantes & Aerts, 2012; and Gelman, Jakulin, Pittau, & Su, 2008; for a similar procedure, see Lago et al., 2019).

All models included the fixed effect Condition and a random intercept for items. For all models, we additionally tested for inclusion of the covariates 'session' (first vs. second session), 'trial number', and the following characteristics of the items and, when relevant (Experiment 2), their stems or embedded stems: word class, length in letters and syllables, imageability, frequency, and word class (see Sassenhagen & Alday, 2016). These were all included as centered continuous covariates, except for word class, which was a categorical variable. Inclusion of the additional covariates was tested step-wise with a bottom-up approach, starting from the model with the simplest structure. Each additional covariate was tested for inclusion separately. The model with and without the additional covariate were compared, and the latter was included only in case it significantly improved the model fit, as tested via likelihood ratio chi-square tests. The same procedure was adopted for adding the relevant random slopes (Baayen, 2008). The dependent variables, the fixed effects, and the random structure of each model are described in the Results and Discussion section of each experiment. Results are reported in terms of coefficients in log odds (*b*), standard errors (SE), *z*-statistics, and *p*-value, as obtained from the model output.

Experiment 1

Materials

Forty prefixed and 40 simple words were presented for reading aloud, together with 20 filler simple words, for a total of 100 items[2]. All prefixed words contained a stem and a prefix, and no other derivational morphemes. Materials in the two conditions were matched pair-wise for word-class (14 adjectives, 12 nouns, and 14 verbs in each condition). They were additionally matched as closely as possible for frequency and length in letters and syllables. A summary of the item characteristics is provided in Table 3. Items were distributed across two blocks, with a break between the two blocks.

Table 3. Mean stimulus properties in Experiment 1 (standard deviations in parenthesis).

Condition	Frequency	Letters	Syllables
Simple (N=40)	4.74 (11.08)	6.50 (0.75)	1.98 (0.16)
Prefixed (N=40)	6.78 (17.80)	7.03 (1.17)	2.38 (0.49)

Results and Discussion

NN produced more errors with prefixed compared to simple words (error rates, prefixed: 30/80, 37.5%; simple 12/80, 15%). We fitted a binary logistic regression to error rate (1 = error; 0 = no error) with the fixed effect Condition (simple vs. prefixed). The best-fit model additionally included the covariates Word Class and Session and a random slope for Session by item. The model showed a significant effect of Condition (Simple vs. Prefixed: b = -1.555, SE = 0.525, z = -2.964, p = .003) and of Word Class, but only for adjectives compared to nouns (Adjective vs. Noun: b = 1.806, SE = 0.641, z = 2.819, p = .005; Verb vs. Noun: b = 0.548, SE = 0.654, z = 0.838, p = .402), as well as a significant effect of Session (b = 4.566, SE = 0.794, z = 5.751, p < .00001; number of errors, Session 1 14/80, 17.5%; Session 2 28/80, 35%).

Of the total number of errors with prefixed words, 60% (18/30) were affix errors; of these, 83.33% (15/18) were prefix omissions, 11.11% (2/18) were substitutions, and 5.56% (1/18) neologisms. Note that prefixes were omitted irrespective of the stress pattern: 53.33% (8/15) of affix omissions occurred when prefixes were stressed and 46.67% (7/15) when they were not stressed.

Results from Experiment 1 suggest an advantage for simple over prefixed words, in line with our expectations, based on previous research on prefixed derived words (Semenza et al., 2002) and, more in general, with previous research on other types of complex words (e.g. Luzzatti et al., 2001; Mondini et al., 2012). In the following experiments, we further investigated the nature of morphological errors with prefixed words, i.e. if these are distinguishable from visual errors (Experiment 2) and what types of errors affect prefixes as compared to suffixes (Experiment 2 and 3).

EXPERIMENT 2

Materials

The experiment included 50 prefixed items (e.g. *ungleich* 'unequal' [un][*gleich* 'equal']), 50 final embedding items (*Gazelle* 'gazelle' [*Zelle* 'cell']), 40 suffixed items (*kalkig* 'limy, chalky' [*Kalk* 'limestone'][ig]), and 40 initial embedding items (*Notiz* 'note' [*Not* 'need/misery']). Twenty filler simple words with no embedded stems were additionally presented, for a total of 200 words. All items were distributed across three blocks, with a break between blocks.

Item characteristics are presented in Table 4. All stimuli and their (embedded) stems were matched across conditions as closely as possible in terms of frequency, length in letters and syllables, and imageability[3]. Prefixed and final embedding items were additionally matched as closely as possible for stress pattern (see Kay, 1988): the (embedded) stem was stressed in 39 prefixed items and in 37 final embedding items. To achieve matching in the two conditions for stress pattern, we had to include many prefixed verbs, for a total of 39 verbs, 6 adjectives, and 5 nouns in the 'prefixed' condition. In contrast, we were not able to find verbs with embedded stems that were suitable for inclusion in the final embedding condition, which included 8 adjectives, 1 adverb, and 41 nouns. As for the suffixed and initial embedding items, all suffixed words took the word stress on their stem, while this was the case only for 24 out of 40 final embedding items. Although it was not possible to perfectly match the items for all their properties, these (including word class) were included in the statistical models we fitted, so that the models account for possible effects arising from differences in stimulus properties rather than from differences between conditions.

Table 4. Mean stimulus properties in Experiment 2 (standard deviations in parenthesis).

Condition	Frequency	Letters	Syllables	Imageability
Prefixed (N = 50)				
Word	6.31 (8.80)	8.10 (1.13)	2.78 (0.42)	4.13 (1.15)
Stem	42.70 (48.88)	5.74 (1.29)	1.70 (0.46)	4.49 (1.23)
Final Embedding (N = 50)				
Word	12.96 (20.67)	6.34 (1.00)	2.12 (0.33)	4.31 (1.53)
Stem	50.64 (113.23)	3.90 (0.95)	1.12 (0.33)	4.91 (1.65)
Suffixed (N = 40)				
Word	6.23 (14.86)	8.13 (1.36)	2.03 (0.16)	5.39 (0.94)
Stem	47.46 (77.19)	4.90 (1.01)	1.08 (0.27)	5.77 (0.95)
Initial Embedding (N = 40)				
Word	6.68 (10.27)	6.38 (1.05)	2.13 (0.33)	5.46 (1.27)
Stem	32.92 (62.03)	3.85 (0.80)	1.15 (0.36)	5.43 (1.14)

Results and Discussion

NN produced a similar number of errors in all conditions. Respectively, 33% (33/100) and 31% (31/100) of his responses in the prefixed and final embedding conditions were incorrect. As for the suffixed and initial embedding conditions, 33.65% (27/80) and 21.25% (17/80) of NN's responses were incorrect. For this analysis, a binary logistic regression model including all four conditions was fit to error rate (1 = error; 0 = no error). For all analyses we report here, the factor Condition was coded with successive contrasts, so that each level was compared to the successive one, allowing a direct comparison of final embedding items to prefixed items, prefixed to suffixed items, and suffixed to initial embedding items. The best-fit model did not include any additional fixed factors. No comparison was statistically significant (final embedding vs. prefixed: *b*

= 0.102, SE = 0.350, *z* = 0.292, *p* = .770; prefixed vs. suffixed: *b* = 0.035, SE = 0.366, *z* = 0.097, *p* = .923; suffixed vs. initial embedding: *b* = -0.688, SE = 0.412, *z* = -1.683, *p* = .095).

We then analyzed the number and types of affix errors in the different conditions. These are summarized in Table 5. The number of affix errors was similar for prefixed and final embedding items (respectively 36.36% and 41.94%) but slightly smaller for suffixed words (25.93%). No affix error was produced with initial embedding items. We fitted a binary logistic regression with affix error as dependent variable (1= affix error; 0 = other error) and Condition as fixed effect. The best-fit model additionally included the covariate Word Frequency (*b* = -0.626, SE = 0.410, *z* = -1.525, *p* = .127). As for effects of Condition, the only contrast that approached significance was the one between suffixed and initial embedding items (*b* = -2.791, SE = 1.506, *z* = -1.854, *p* = .064), while there was no effect of Condition for the other contrasts (final embedding vs. prefixed *b* = -0.297, SE = 0.514, *z* = -0.576, *p* = .564; prefixed vs. suffixed: *b* = -0.621, SE = 0.569, *z* = -1.092, *p* = .275).

Table 5. Summary of affix errors in Experiment 2.

Error Type	Prefixed	Final Emb.	Suffixed	Initial Emb.
Affix omission	8/12 (66.67%)	1/13 (7.69%)	0/7 (0%)	-
Affix substitution	3/12 (25%)	4/13 (30.77%)	7/7 (100%)	-
Affix neologism	1/12 (8.33%)	8/13 (61.54%)	0/7 (0%)	-
Total affix errors	12/33 (36.36%)	13/31 (41.94%)	7/27 (25.93%)	0/17 (0%)

Regarding the types of affix errors produced in the different conditions, prefixes were more often omitted, while word beginnings of final embedding items were rather replaced with neologisms, and suffixes were exclusively substituted. We fitted two binary logistic regression models, one testing the number of omissions versus any other type of affix error (1 = omission; 0 = other), the other testing the number of substitutions versus other affix errors (1 = substitution; 0 = other) in the different conditions; the initial embedding condition could not be included because there were no affix errors. In the model testing omissions, the effect of Condition was significant (final embedding vs. prefixed: b = 3.200, SE = 1.381, z = 2.317, p = .021; prefixed vs. suffixed: b = -3.339, SE = 1.495, z = -2.233, p = .026), indicating that significantly more omissions were produced with prefixed words compared to both final embedding items and suffixed items. The best-fit model also included the two covariates Trial Number (b = -1.287, SE = 0.653, z = -1.970, p = .049) and Stem Frequency (b = -2.580, SE = 1.583, z = -1.630, p = .103). In the model testing substitutions, the effect of Condition was significant for the comparison between prefixed and suffixed words (b = 3.810, SE = 1.611, z = 2.366, p = .018), but not for the comparison between final embedding and prefixed items (b = -0.098, SE = 0.892, z = -0.110, p = .913), reflecting the numerical tendencies from Table 5. The best-fit model did not include any additional covariate.

In sum, prefixed words did not yield significantly more errors than final embedding items, and the same was true for the comparison between suffixed and initial embedding items. This is in line with the findings from previous studies comparing suffixed words to words containing word-initial embeddings, which indeed reported differences between conditions only in the types of errors produced, but not in the error rates (e.g. Badecker & Caramazza, 1991; Rastle et al., 2006). As for affix errors, their numbers were similar in the prefixed and final embedding conditions, which was not in line with our predictions. However, we did find that the two conditions differed significantly for the types of affix errors that were produced: while prefixes were mostly omitted, non-morphological word-beginnings (such as **pa-* in Palast 'palace') were substituted with neologisms. Error types with prefixes were also significantly different from error types with suffixes, which were exclusively substituted.

As it has been pointed out in previous literature (e.g. Luzzatti et al., 2001), whether affixes are omitted or substituted in morphological errors can be influenced by the set of potential responses to a morphologically complex word, i.e. the number of words that are morphologically similar to the target word. For example, potential (incorrect) responses to the word *usable* are *user*, *useful*, *useless*, and *use.* Consequently, this factor may also account for the difference between prefixes and suffixes that we observed in Experiment 2. From the dlexDB corpus (Heister et al., 2011), we computed the number of possible responses to the prefixed and suffixed words of Experiment 2. We considered possible responses to prefixed items all words from the corpus ending with the same stem of the prefixed word. Similarly, possible responses to suffixed words were all words beginning with the given stem. We found that the number of possible responses to the prefixed words was smaller (*M* 268.8, SD 414.4) than the number of possible responses to suffixed words (*M* 796.2, SD 828.2). Therefore, this factor was more carefully considered in Experiment 3.

EXPERIMENT 3

Materials

The experiment included 350 items, of which 200 were prefixed derived words and 150 were simple words. Of the 700 trials (350 items tested twice), 93 were excluded because of a technical failure in Session 2. Respectively, 60.5% (121/200) of the prefixed items and 78.7% (118/150) of the simple items were nouns, while the remaining items in both conditions were adjectives. The prefixed words contained three morphemes: a prefix, a monosyllabic stem, and a suffix. Simple and prefixed items were as closely matched as possible in terms of frequency and they were all three-syllabic. However, due to the general characteristics of German simple words, items in the derived condition were on average longer than items in the simple condition. Item characteristics are summarized in Table 6.

Table 6. Mean stimulus properties in Experiment 3 (standard deviations in parenthesis).

Condition	Frequency	Letters	Syllables
Simple (N=150)	5.15 (7.13)	7.46 (0.91)	3.00 (0.00)
Prefixed (N=200)	4.16 (9.93)	9.89 (1.18)	3.00 (0.00)

In all prefixed three-morphemic words, the word stress was on the stem. For each stimulus, we computed a factor labeled 'alternative response to affix' for both prefixes and suffixes. We first removed the suffix from each stimulus (e.g. -*ung* from the stimulus *Entgiftung* 'detoxification') and obtained the number of words beginning with the same prefix and stem (e.g. all words that begin with *entgift-*), excluding inflected forms. Then, we removed the prefix from each stimulus (e.g. *ent-* from the stimulus *Entgiftung*) and extracted the number of words ending with the same stem and suffix (e.g. all words ending in -*giftung*). The mean number of 'alternative responses to affixes' was larger for prefixes (prefixes: M 136.11, SD 322.19, range 0-3321; suffixes M 82.32, SD 143.67, range 2-1219). If, in this experiment, we find again a larger number of affix errors with prefixes than suffixes, then this cannot be due to the number of alternative responses that can be created by substituting the affix. This factor was additionally tested for inclusion in the statistical model testing the occurrence of omissions versus substitutions with prefixes and suffixes.

Results and Discussion

NN produced more errors with the prefixed items (260/343; 75.80%) than with the simple items (152/274; 57.58%). To test this statistically, we fitted a binary logistic regression model to error rate (1 = error; 0 = no error) with Condition as fixed factor. The best-fit model additionally included the covariates Length in Letters and Word Class. Despite the numerical trend for a disadvantage for prefixed compared to simple words, the effect of Condition was not significant (b = -0.221, SE = 0.293, z = -0.754, p = .451), while both Length in Letters and Word-Class (nouns vs. adjectives) had a significant effect (respectively: b = 0.330, SE = 0.153, z = 2.155, p = .031; b = -1.193, SE = 0.247, z = -4.832, p < .00001). This indicates that the advantage found for simple words was in fact a by-product of the differences between conditions in number of letters and word class.

Similarly to Experiment 2, we then analyzed the errors involving prefixes and suffixes, leaving the stem spared (see Table 7). Affix errors accounted for 29.23% (76/260) of the total of number errors. Of these errors, 32.89% (25/76) involved the prefix, 48.68% (37/76) involved the suffix, and 18.42% (14/76) involved both affixes.

Table 7. Summary of affix errors (only involving either the prefix or the suffix) in Experiment 3.

Error Type	Prefix	Suffix
Affix omission	14/25 (56%)	0/37 (0%)
Affix substitution	11/25 (44%)	37/37 (100%)
Affix neologism	0/25 (0%)	0/37 (0%)
Tot. affix errors	25/76 (32.89%)	37/76 (48.68%)

There was no significant difference in the amount of errors involving prefixes versus suffixes, as tested by the intercept of a binary logistic regression model fitted with affix error as dependent variable (1 = prefix, 0 = suffix; b = -1.517, SE = 1.031, z = -1.471, p = .141). The best-fit model additionally included the covariate Word Class (nouns vs. adjectives: b = 1.615. SE = 1.122, z = 1.440, p = .150). We then compared the types of errors produced with prefixes and suffixes, by considering those errors affecting either one of the affixes, leaving the rest of the word spared. Suffixes were exclusively replaced with other suffixes, while prefixes were sometimes substituted, but more often omitted. We tested this outcome in a binary logistic regression model with error type as dependent variable (omission = 1; substitution = 0) and Affix Type as fixed factor (prefix vs. suffix). The effect of Affix Type was significant (b = 5.152, SE = 1.400, z = 3.679, p = .0002). Note that adding the factor 'alternative response to affix' did not improve the model fit, hence it could not explain the variance in the dataset. Instead, the best-fit model additionally included the covariates Trial Number (b = 0.988, SE = 0.522, z = 1.891, p = .059) and Length in Letters (b = 0.987, SE = 0.584, z = 1.689, p = .091).

In sum, in the overall error rates, we could not observe a disadvantage for prefixed words with the types of items we tested in this experiment, possibly because any effect of morphologically complexity were overridden by word length. As for the types of errors with prefixes and suffixes, we replicated the finding from Experiment 2 of more omissions with prefixes and exclusively substitutions for suffixes.

Note that there is yet another factor that may explain the larger number of omissions with prefixes, additionally to those that we considered. For the majority of the items we selected for Experiment 3, a suffix omission results in a non-word (185/200, 92.5%), while a prefix omissions results in a non-word in only half (100/200) of the items. In a post-hoc analysis, we fitted a model to the errors with prefixes, including error type as dependent variable (substitution = 1; omission = 0) and 'result of omission' (existing word vs. non-word) as fixed effect. This factor did not have a significant effect on the types of errors produced (b = -1.047, SE = 1.094, z = -0.957, p = .336), suggesting that whether omitting the prefix results in an existing or in a non-existing word could not explain the types of errors produced.

GENERAL DISCUSSION

We investigated three main questions about how prefixed words are impaired in a German individual with phonological dyslexia. First, whether more errors are produced when reading aloud prefixed words compared to matched simple words. Second, whether morphological errors with prefixed words are dissociable from visual errors produced with words containing word-final embedded stems. Finally, whether errors affecting prefixes differ from errors affecting suffixes. The answer to these questions does not only provide a characterization of the impairment of prefixed words in phonological dyslexia but may constitute an improvement of our knowledge of how prefixed words are processed. In phonological dyslexia, reading is believed to reflect the use of the lexical route of reading, unaided and uninfluenced by the sub-lexical route where grapheme-to-phoneme conversion takes place. Morphological errors would derive from the decomposed status of complex words in the mental lexicon. Thus an individual affected by phonological dyslexia would retrieve the stem adding to it the wrong affix, without the benefit of a possible correction by an impaired grapheme-to-phoneme conversion system.

A series of studies found that individuals with morphological impairments produce more errors with complex words than with matched simple words. This has been reported in several studies on suffixed words – both inflected and derived – and compound words (e.g. Luzzatti et al., 2001; Mondini et al., 2012), but also for prefixed derived words (Semenza et al., 2002). Our results from Experiment 1 replicate previous findings of an advantage for simple words over prefixed words. Importantly, the opposite dissociation, with complex words being more spared than simple words, has also been reported in the literature, at least in spelling (Badecker, Hillis, & Caramazza, 1990). This dissociation between simple and complex words has been taken as evidence for different mechanisms underlying the processing of simple and complex words, the former being stored and retrieved as whole units while the latter being decomposed into their constituents (e.g. Hamilton & Coslett, 2008). Note that the dissociation between simple and complex words in the error rates was not replicated for the three-morphemic items we tested in Experiment 3. Because the items in this experiment were considerably longer, and error rates were generally larger than in the other two experiments, we suggest that the increased word length made the task too difficult across the board.

Further evidence for a level of morphological decomposition of complex words in acquired dyslexia comes from the types of errors produced with complex words, which often reflect the morphological structure of the complex word (so-called morphological errors; Semenza & Mondini, 2015). Therefore, the second question we investigated, in Experiment 2, was whether morphological errors involving prefixes are truly morphological, i.e. if they are dissociable from the types of errors produced with items containing word-final embedded stems. Unlike previous research on suffixed words (e.g. Rastle et al., 2006), we found comparable numbers of affix errors affecting prefixes and non-morphological word beginnings (e.g. **pa-* in *Palast* 'palace'). However, prefixed and final embedding items elicited significantly different types of affix errors: mostly omissions in the case of prefixed words, but mostly neologisms in the final embedding condition. If, based on the similar numbers of affix errors in the two conditions, we assumed that reading aloud of prefixed and final embedding items are based on the same mechanisms, then we would also expect to find omissions for non-morphological word beginnings, just like prefixes. Instead, our results suggest that, when producing a word containing a word-final embedded stem, an attempt is made to produce its full form. Therefore, in the present study, we were able to show for the first time that morphological errors with prefixed words are dissociable from errors produced with words containing embedded stems, even after controlling for all relevant variables such as full-form and stem frequency and imageability (Funnell, 1987).

This finding represents a relevant contribution to the current literature on morphological processing and morphological impairments for several reasons. First, theories that claim that prefixed words do not undergo morphological decomposition do not find support in our data, although this does not rule out that the decomposition of prefixed words may be more costly or delayed, at least in specific stages of visual word recognition (see e.g. Ferrari Bridgers & Kacinik, 2017; Kim et al., 2015). Second, while morphological errors in suffixed words may be confounded with general neglect of word endings (Castles et al., 1996; Hamilton & Coslett, 2008; Shallice & Warrington, 1975), this is not the case in prefixed words, which therefore represent a stronger case in support of the genuine morphological nature of morphological errors. Finally, note that in all three experiments, as well as in the preliminary assessments, NN did produce some visual errors (e.g. ***bedrücken*** 'oppress' → «Brücken» 'bridges', exp. 2; ***Allergie*** 'allergy' → «Energie» 'energy', exp. 3), but he never produced semantic errors. This is crucial because, as pointed out by Badecker and Caramazza (1987), while different error patterns for affixed words versus words with embeddings rule out that morphological errors are visual in nature, one cannot rule out that these are semantic in nature if the participants also produce semantic errors, which was indeed the case for most cases reported in the literature (e.g. Job & Sartori, 1984; Kay, 1988; Rastle et al., 2006).

Whether morphological errors are genuinely morphological in nature was additionally investigated with a set of truly suffixed items and items with word-initial embedded stems, to replicate previous findings on suffixed words (e.g. Rastle et al., 2006). We found some affix errors with suffixed words and no affix errors in the initial embedding condition, but the difference between the two conditions was only marginally significant. Hence, possibly due to lack of power, we could not fully replicate the previous results on suffixed words by Rastle et al. (2006). We also could not perform further analyses on the error types because of the lack of affix errors in the initial embedding condition.

Our final question concerned the different types of errors produced with prefixes and suffixes, which we investigated in Experiment 2 and 3. Our results showed a difference in the types of error produced: suffixes were exclusively substituted, while prefixes were more often omitted, thus providing further characterization of the impairment of prefixed words in acquired dyslexia. This was true both when prefixes and suffixes occurred in different sets of matched prefixed and suffixed words (Experiment 2), and when prefixes and suffixes occurred within the same three-morphemic words (Experiment 3). In line with our predictions, we showed for the first time that the specific properties of prefixes and suffixes not only affect how early and how easily these are learned (Kuczaj, 1979; Slobin, 1973), but also how these are affected in language loss. Because affixes encode properties of the stem, the fact that prefixes precede the stem makes them less prone to being learned (Ramscar, 2012; St. Clair et al., 2009) and, as we may suggest here, more prone to being affected in language loss. We note that this account may be strictly related to the notion of *grammatical head*, i.e. the component of the complex word that encodes its grammatical properties, such as gender or word class. Indeed, while suffixes are generally the grammatical head of derived words, the head of a prefixed word is generally, though not always, its stem (Scalise & Guevara, 2005; Williams, 1981). The properties of the stem that prefixes encode tend to be rather semantic in nature; for example, for the adjective *unschön* 'not beautiful' [un][schön 'beautiful'], it is the stem *schön* that determines that the word is an adjective, while the prefix contributes to the meaning of the stem by forming its negative form. Hence, the grammatical properties of suffixes may make them more salient for the processor and thus less likely to be affected in acquired dyslexia. What remains to be assessed is whether this generally affects how prefixed words are impaired in language loss (and, possibly, processed), or whether this is a bare *headedness effect*, i.e. it only reflects a general tendency of heads to be retained more that non-head constituents (see the research on compounds: Jarema, Perlak, & Semenza, 2010; Marelli et al., 2013; Semenza et al., 2011) and it would disappear if we tested the (much less widespread) cases of prefixed words with prefix heads. In both cases however, because headedness is a morphological property of complex words, we suggest that the observed difference between prefixes and suffixes additionally confirms the morphological nature of affix errors.

NOTES

1. Although we attempted to mirror the three conditions included in the study by Rastle et al. (2006) by having prefixed items, pseudo-prefixed items, and items with word-final embeddings, this was not possible because of the many restrictions on the item properties (length, imageability, and frequency). However, the 'final embedding' condition included 22 items that can be classified as pseudo-prefixed, as they contained both an embedded stem and a pseudo-prefix (e.g. *Inhalt* 'content' [in][halt 'stop']). Because we did not find any difference between the pseudo-prefixed items and the final embedding items without a pseudo-prefix, this is not further discussed. Note, additionally, that Rastle et al. (2006) found a significant difference in the number and types of affix errors between suffixed words and pseudo-suffixed words and between suffixed words and words with initial

embeddings, but no evidence that pseudo-suffixed words and words with initial embeddings behave differently.

2. One simple item (*Fleck* 'stain') contained a typo (*Flecke*). However, because NN produced a corrected version of the item in both sessions («Flecken» 'stains', plural form of *Fleck*), the item was not removed and the responses were scored as correct.
3. All experimental items were selected from a pool of words for which we had previously collected imageability ratings of the full forms and, if applicable, their stems (or embedded stems), in different online surveys. In all surveys, ratings were provided on a 1-7 scale (1 = lowest imageability).

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APPENDIX A

Excerpts of NN's Spontaneous Speech (Stroke Story)

Note: Parentheses contain comments or Standard German equivalents of dialectal or colloquial phrases

Experimenter: Dachten Sie es ist Migräne erst, oder?
[You thought it is a migraine at first, right?]

NN: Ja ja ja ja hmh… und dann meine Frau kam äh was issn (ist denn) mit dür (dir) äh hab (habe) Kapfschmm äh hier Migräne ja und denn mmh is (ist) äh naja äh.. oa Arbeit is (ist) sie Arbeit gegangen und ich… äh bilt und dann kamen die tinder äh und dann äh ja die kam alme Frau nanu? Pullern äh Bebett und uää (points to his tongue) und torkelt ja und dann…

[Yes yes yes yes hmh… and then my wife came äh what's wrong with you äh I have a Kapfschmm (distortion of Kopfschmerzen, headache) äh here migraine yes äh and then mmh it is äh well äh… oa work she went working and I… äh *bilt and then came the* tinder äh and then äh yes they came *alme wife* nanu? Piddle äh *Bebett and uää (points to his tongue) and staggers yes and then…]

Experimenter: Sie konnten nicht mehr sprechen, also war alles ganz weg?

[You could no longer speak, then completely?]

NN: Ja ja und kann äh Krankenhaus und dann äh ääh. (name of a place) ja.

[Yes yes and can äh hospital and then äh ääh. (name of a place) yes.]

Experimenter: Aha da waren Sie im Krankenhaus?

[Aha were you then in a hospital?]

NN: Ja. Der hat gut Doktor wes es (weiß ich) nicht ja (name of a person) aber ihr habt noch keine äh mm na wie heißt det (das) äh… na wie heißt det (das) die ne (eine) was…

[Yes. This has good (missing inflection) doctor I don't know yes (name of a person) but you still have no äh mm well how is this called äh… well how is this called the a what…]

APPENDIX B

Experimental Items

Experiment 1

Simple Items (N = 40)

Advent 'advent'
Balsam 'balsam'
bizarr 'bizarre'
defect 'faulty'
dezent 'decent'
Dozent 'instructor'
Effekt 'effect'
Flasche 'bottle'
Fleck 'stain'
fragil 'fragile'
giften 'rile'
glimmen 'glow'
Grenze 'border'
Gulasch 'goulash'
immens 'immense'
kaputt 'broken'
Kitzel 'tickle'
korrupt 'corrupt'
lehnen 'lean'
naschen 'snack'
obszön 'obscene'
orange 'orange'
Paddel 'paddle'
Pickel 'pimple'
Platte 'panel'
pompös 'pretentious'
prahlen 'brag'
robust 'robust'
schieben 'push'
schielen 'squint'
schreien 'scream'
schweben 'float'
simpel 'simple'
skurril 'bizarre'
sprengen 'burst open'
stehlen 'steal'
stinken 'stink'
türkis 'turquoise'
weigern 'refuse'
wispern 'whisper'

Prefixed Items (N = 40)

befeinden 'be hostile towards'
befinden 'be located'
befrieden 'bring peace to'
begnaden 'give the grace/gift of'
Begriff 'term'
bekennen 'admit'
beleben 'liven up/resuscitate'
beloben 'praise'
belügen 'lie'
besagen 'prove/mean'
beschaffen 'procure'
Beschluss 'decision/resolution'
beschuhen 'equip with shoes'
betiteln 'give a title'
betreffen 'affect/concern'
Gehirn 'brain'
Gewehr 'rifle'
unbillig 'expensive'
undicht 'not waterproof'
Unding 'absurdity'

uneben 'uneven'
unedel 'not noble'
unernst 'not serious'
unklar 'unclear'
unklug 'unwise'
unlieb 'not nice/not welcome'
Unrecht 'injustice'
unreif 'immature'
unrein 'impure'
unrund 'not round'
unsanft 'rough'
untief 'not deep'
unwahr 'untrue'
Urbild 'model/prototype'
Urform 'archetype'
Urkraft 'elemental force'
Urtext 'original text'
Urvolk 'primitive people/original inhabitants'
Urwelt 'primeval world'
versagen 'fail/malfunction'

Experiment 2

Final Embedding Items (Embedded Stems) (N = 50)

Autor 'author' (Tor 'gate/door')
Barock 'baroque' (Rock 'skirt/rock (music)')
Bazar 'bazar' (Zar 'czar')
Bereich 'area' (reich 'rich')
Beton 'concrete (material)' (Ton 'sound')
brutal 'brutal' (Tal 'valley')
Demut 'humility' (Mut 'courage')
Diskurs 'discourse' (Kurs 'course')
Eleganz 'elegance' (ganz 'entire')
Faktor 'factor' (Tor 'gate/door')
formal 'formal' (mal 'once/time')
Gazelle 'gazelle' (Zelle 'cell')
geheim 'secret/confidential' (Heim 'home')
Gemahl 'spouse' (Mahl 'meal')
Genuss 'pleasure' (Nuss 'nut')
gering 'small' (Ring 'ring')
Geschlecht 'gender' (schlecht 'bad')
gestern 'yesterday' (Stern 'star')
Gewand 'robe' (Wand 'wall')
Gewicht 'weight' (Wicht 'small child')
Heirat 'marriage' (Rat 'advice/council')
Hering 'herring' (Ring 'ring')
Inhalt 'content' (Halt 'stop')
intakt 'intact' (Takt 'time/beat')
Kanton 'canton' (Ton 'sound')
Karat 'carat' (Rat 'advice/council')
Karton 'carton' (Ton 'sound')
Komfort 'comfort' (fort 'forth')
Kompass 'compass' (Pass 'pass')
Konkurs 'insolvency' (Kurs 'course')
Kontakt 'contact' (Takt 'time/beat')
Kristall 'crystal' (Stall 'stable/cowshed')
Mentor 'mentor' (Tor 'gate/door')
Merkur 'mercury' (Kur 'cure')
Motor 'motor' (Tor 'gate/door')
Neurose 'neurosis' (Rose 'rose')
normal 'normal' (mal 'once/time')
Palast 'palace' (Last 'load')
pauschal 'lump/fixed' (Schal 'scarf')
Programm 'program' (Gramm 'gram')

Protest 'protest' (Test 'test')
Sekunde 'second' (Kunde 'customer')
Sklerose 'sclerosis' (Rose 'rose')
Sonett 'sonnet' (nett 'nice')
Tutor 'tutor' (Tor 'gate/door')
Urkunde 'certificate' (Kunde 'customer')
Urteil 'sentence/judgment' (Teil 'piece')
vital 'vital' (Tal 'valley')
Vokabel 'word' (Kabel 'cable')
Zitat 'quote' (Tat 'action/crime')

Prefixed Items (Stems) (N = 50)

beachten 'notice' (achten 'pay attention to')
beatmen 'ventilate' (atmen 'breath')
bebildern 'illustrate' (Bild/Bilder 'panting/s')
bedachen 'provide with a roof' (Dach 'roof')
bedanken 'thank' (danken 'dank')
bedecken 'cover' (decken 'cover')
bedrohen 'threaten' (drohen 'threaten')
bedrücken 'oppress' (drücken 'push')
befahren 'drive on/along' (fahren 'drive')
befliegen 'fly' (fliegen 'fly')
befördern 'transport' (fördern 'sponsor')
befragen 'question' (fragen 'ask')
begatten 'mate' (Gatte 'spouse')
begleiten 'accompany' (gleiten 'slide')
behalten 'keep' (halten 'hold/stop')
behandeln 'treat' (handeln 'trade')
beklagen 'complain' (klagen 'sue')
beladen 'load' (laden 'load')
belasten 'burden' (Last 'weight')
belehren 'instruct' (lehren 'teach')
beleuchten 'illuminate' (leuchten 'glow')
benennen 'name/nominate' (nennen 'name/list')
berechnen 'calculate' (rechnen 'calculate')
berufen 'call/appoint' (rufen 'call')
beschenken 'give (gift)' (schenken 'give (gift)')
beschlagen 'put metal fits' (schlagen 'hit')
beschützen 'protect/shelter' (schützen 'protect')
besprechen 'discuss' (sprechen 'speak')
besprengen 'spray' (sprengen 'burst open')
bewerten 'evaluate' (Wert 'value')
bewohnen 'occupy/inhabit' (wohnen 'live')
bezeichnen 'name/label' (zeichnen 'draw/sketch')
beziffern 'number/estimate' (Ziffer 'digit')
unfein 'indelicate/not nice' (fein 'delicate/nice')
unfrei 'not free' (frei 'free')
ungleich 'unequal' (gleich 'equal')
Unglück 'disaster/misfortune' (Glück 'luck')
Unkraut 'weed' (Kraut 'herb')
unscharf 'fuzzy/imprecise' (scharf 'sharp')
unschön 'ugly' (schön 'beautiful')
Unsinn 'nonsense' (Sinn 'sense')
untreu 'unfaithful' (treu 'faithful')
Urstoff 'primary element' (Stoff 'material/fabric')
Urwald 'jungle/primeval forest (Wald 'wood/forest')
verbauen 'obstruct/build up' (bauen 'build')
verhüten 'prevent/take precautions' (hüten 'protect')

verleben ‘spend’ (leben ‘live’)
verlegen ‘misplace/reschedule’ (legen ‘lay’)
verlesen ‘misread’ (lesen ‘read’)
verloben ‘get engaged’ (loben ‘praise’)

Initial Embedding Items (Embedded Stems) (N = 40)

Algebra ‘algebra’ (Alge ‘alga’)
Altar ‘altar’ (alt ‘old’)
Bandit ‘bandit’ (Band ‘tie/band/tape’)
Bankett ‘banquet’ (Bank ‘bank’)
Barke ‘boat’ (Bar ‘bar’)
Baron ‘baron’ (Bar ‘bar’)
Bottich ‘tub’ (Bot ‘bot’)
Deichsel ‘shaft/pole’ (Deich ‘dike/barrier’)
Formel ‘formula’ (Form ‘form’)
Handel ‘trade/business’ (Hand ‘hand’)
Hangar ‘hangar’ (Hang ‘slope’)
Kalkül ‘calculation’ (Kalk ‘limestone’)
Kartell ‘cartel’ (Karte ‘card’)
Kitzel ‘tickle’ (Kitz ‘fawn’)
Kolonne ‘column’ (Kolon ‘colon’)
Laune ‘mood’ (lau ‘lukewarm’)
Mineral ‘mineral’ (Mine ‘mine’)
Modell ‘model’ (Mode ‘fashion’)
Muskel ‘muscle’ (Mus ‘mush/puree’)
Muslim ‘muslim’ (Mus ‘mush/puree’)
neutral ‘neutral’ (neu ‘new’)
Notar ‘notary’ (Not ‘need/misery’)
Notiz ‘note’ (Not ‘need/misery’)
Papagei ‘parrot’ (Papa ‘dad’)
Planet ‘planet’ (Plan ‘plan’)
Plankton ‘plankton’ (Plan ‘plan’)
Radio ‘radio’ (Rad ‘wheel’)
Schachtel ‘box’ (Schach ‘chess’)
Schaufel ‘shovel’ (Schau ‘show’)
Skalpell ‘scalpel’ (Skalp ‘scalp’)
Spange ‘clasp’ (Span ‘shavings/filings’)
Spanne ‘span’ (Span ‘shavings/filings’)
Spindel ‘spindle’ (Spind ‘locker’)
Standard ‘standard’ (Stand ‘state/stand’)
Talent ‘talent’ (Tal ‘valley’)
Taufe ‘baptism’ (Tau ‘dew’)
Tonne ‘barrel/ton’ (Ton ‘sound’)
Torsion ‘torsion/twist’ (Tor ‘gate/door’)
Wachtel ‘quail’ (wach ‘awake’)
Wandel ‘change’ (Wand ‘wall’)

Suffixed Items (Stems) (N = 40)

Ascher ‘ashtray’ (Asche ‘ash’)
Bildung ‘education’ (Bild ‘picture’)
Blindheit ‘blindness’ (blind ‘blind’)
Blutung ‘bleeding’ (Blut ‘blood’)
Dünnheit ‘thinness’ (dünn ‘thin’)
ekelhaft ‘disgusting (Ekel ‘disgust’)
Flachheit ‘flatness’ (flach ‘flat’)
Fleischer ‘butcher’ (Fleisch ‘meat’)
frostig ‘frosty’ (Frost ‘frost’)
fruchtbar ‘fertile/fruitful’ (Frucht ‘fruit’)
fruchtig ‘fruity’ (Frucht ‘fruit’)
haarig ‘hairy’ (Haar ‘hair’)
jagdbar ‘allowed to be hunted’ (Jagd ‘hunt’)
kalkig ‘limy, chalky’ (Kalk ‘limestone’)

kindlich 'childlike' (Kind 'child')
krankhaft 'diseased/pathological' (krank 'ill')
Krankheit 'illness' (krank 'ill')
Leerung 'emptying' (leer 'empty')
Lichtung 'clearing/glade' (Licht 'light')
Musiker 'musician' (Musik 'music')
Nacktheit 'nakedness' (nackt 'naked')
Paarung 'mating/combination' (Paar 'pair')
Rauheit 'roughness' (rau 'rough')
reichlich 'abundant' (reich 'rich')
rundlich 'chubby' (rund 'round')
Rundung 'curve' (rund 'round')
salzig 'salty' (Salz 'salt')
Schiefheit 'obliqueness' (schief 'oblique')
Schiffer 'sailor' (Schiff 'ship')
Schlankheit 'slimness' (schlank 'slim')
schmerzhaft 'painful' (Schmerz 'pain')
schmerzlich 'painful/sad' (Schmerz 'pain')
Schönheit 'beauty' (schön 'beautyful')
sportlich 'sporty' (Sport 'sport')
stofflich 'of material' (Stoff 'material')
streitbar 'quarrelsome' (Streit 'quarrel')
Sünder 'sinner' (Sünde 'sin')
tierhaft 'animal-like' (Tier 'animal')
Weichheit 'softness' (weich 'soft')
weltlich 'worldly' (Welt 'world')

Experiment 3

Simple Items (N = 150)

absolut 'absolute'
Adjektiv 'adjective'
Akademie 'academy'
akkurat 'accurate'
aktuell 'current'
Alkohol 'alcohol'
Allergie 'allergy'
Allianz 'alliance'
Alphabet 'alphabet'
Analyse 'analysis'
Anarchie 'anarchy'
Apotheke 'pharmacy'
Aprikose 'apricot'
arrogant 'arrogant'
Assistent 'assistant'
Banane 'banana'
Bibliothek 'library'
Bikini 'bikini'
Blockade 'blockade'
Defizit 'deficit'
Didaktik 'didactics'
digital 'digital'
Diktator 'dictator'
Emotion 'emotion'
Epilepsie 'epilepsy'
Episode 'episode'
exklusiv 'exclusive'
Experte 'expert'
explizit 'explicit'
Fakultät 'faculty'
Ferien 'vacation'
Festival 'festival'
Filiale 'branch/store'
flexibel 'flexible'
Forelle 'trout'
Formular 'form'
Fusion 'fusion'
Ganove 'bandit'
Garage 'garage'
Gardine 'curtain'
Giraffe 'giraffe'
Gitarre 'guitar'
Gorilla 'gorilla'
Grammatik 'grammar'
graziös 'graceful'
Gremium 'committee'
Gymnastik 'gymnastics'
Halunke 'scoundrel'
Harmonie 'harmony'
Hebamme 'midwife/obstetrician'

Hermelin ‘ermine’
Holunder ‘elderberry’
homogen ‘homogenous’
Honorar ‘royalties/fee’
implizit ‘implicit’
Ingenieur ‘engineer’
Journalist ‘journalist’
Kabine ‘cabin’
Kalender ‘calendar’
Kalorie ‘calory’
Kamera ‘camera’
Kamille ‘chamomile’
Kampagne ‘campaign’
Karaffe ‘carafe’
Karamel ‘caramel’
Karotte ‘carrot’
Karriere ‘career’
Kassette ‘cassette’
Kolonie ‘colony’
Kommentar ‘comment/’
kompetent ‘qualified’
Konfetti ‘confetti’
Krawatte ‘tie’
Krokette ‘croquette’
Krokodil ‘crocodile’
Laktose ‘lactose’
Lamelle ‘lamella’
legitim ‘legitimate’
Lektion ‘lesson’
Libelle ‘dragonfly’
liberal ‘liberal’
Magister ‘Master’s degree’
Marzipan ‘marzipan’
maskulin ‘masculine’

Massage ‘massage’
Massaker ‘massacre’
Matrikel ‘matriculation number’
Matrose ‘sailor’
Medizin ‘medicine’
Melone ‘melon’
Minute ‘minute’
Mirakel ‘miracle’
Mission ‘mission’
negativ ‘negative’
Option ‘option’
Papagei ‘parrot’
Paprika ‘paprika’
parallel ‘parallel’
Parmesan ‘parmesan’
Partikel ‘particle’
Passage ‘passage’
Pauschale ‘lump sum’
Plagiat ‘plagiarism’
plausibel ‘plausible’
Portion ‘portion’
positiv ‘positive’
Praline ‘praline/chocolate’
präzise ‘precise’
Premiere ‘première
Publikum ‘audience’
Rakete ‘rocket’
rapide ‘rapid’
Referat ‘lecture/talk’
Region ‘region’
relativ ‘relative’
Risiko ‘risk’

Roboter ‘robot’
Rosmarin ‘rosemary’
Salami ‘salami’
Schublade ‘drawer’
Sekretär ‘secretary’
Sektion ‘section’
Sellerie ‘celery’
Semester ‘semester’
Seminar ‘seminar’
Senator ‘senator’
sensibel ‘sensible’
separat ‘separate’
seriös ‘serious’
Silikon ‘silicon’
Silvester ‘New Year’s Eve’
sozial ‘social’
speziell ‘special’
Strategie ‘strategy’
Tabelle ‘table’
Tablette ‘tablet/pill’
Tastatur ‘keyboard’
Telefon ‘telephone’
Therapie ‘therapy’
Toilette ‘toilet’
tolerant ‘tolerant’
Tomate ‘tomato’
Tragödie ‘tragedy’
transparent ‘transparent’
variabel ‘variable’
vertikal ‘vertical’
visuell ‘visual’
Vitamin ‘vitamin’
Zigarre ‘cigar’
Zigeuner ‘gipsy’

Prefixed Items (N = 200)

beachtlich 'considerable'
bedenklich 'doubious'
Bediener 'operator/agent'
bedrohlich 'threatening'
Beendung 'completion'
befahrbar 'passable/navigable'
befindlich 'that finds oneself'
Befragung 'survey'
Befreier 'liberator'
befremdlich 'strange'
begehbar 'passable'
Begleiter 'companion'
begreiflich 'understandable'
begrifflich 'conceptual'
begründbar 'justifiable'
Begründer 'founder'
beharrlich 'persistent/determined'
beherrschbar 'controllable'
Beherrscher 'ruler/dominating person'
behilflich 'helpful'
Bekehrer 'someone who converts'
Bekleidung 'clothing'
belastbar 'loadable'
Belebung 'vitalization'
belegbar 'verifiable'
belehrbar 'teachable'
bemerkbar 'noticeable'
benützbar 'usable'
Benutzer 'user'
Berater 'consultant'
beruflich 'having to do with one's job'
Beschauer 'viewer'
beschaulich 'contemplative'
beschreibbar 'describable'
Beschulung 'schooling'
bewohnbar 'inhabitable'
bezahlbar 'payable'
entbehrlich 'non-essential'
Entdecker 'discoverer'
Enteisung 'defrosting'
entfaltbar 'unfoldable'
Entfernung 'distance'
entflammbar 'inflammable'
Entfremdung 'alienation'
Entführer 'kidnapper'
entgeltlich 'against payment'
Entgiftung 'detoxification'
Enthaltung 'abstention'
Enthauptung 'beheading'
Enthebung 'release/dismissal'
Entladung 'unloading/discharge'
Entlassung 'dismissal'
Entlastung 'reduction/exonaration'
Entleerung 'emptying'
Entsagung 'renunciation/self-denyal'
Entseelung 'disembodiment'
Entsendung 'dispatch'
Entspannung 'relaxation'
Entstauber 'dust-remover'
Entstellung 'distortion'
Entstörung 'interference suppression'
Entwarnung 'all-clear signal'
Entweihung 'desecration'
Entwertung 'devaluation'
Entwickler 'developer'
entwirrbar 'resolvable'

Entwöhnung 'weaning/withdrawal'
Entziehung 'withdrawal/confiscation'
entzündbar 'inflammable'
erbärmlich 'miserable'
erbaulich 'edifying/elevating'
erdenkbar 'conceivable'
erdenklich 'conceivable'
erfahrbar 'tangible'
erfaßbar 'comprehensible'
Erfinder 'inventor'
erfindlich 'explicable'
erforschbar 'explorable'
Erforscher 'explorer'
erforschlich 'searchable/fathomable'
erfreulich 'pleasant'
erfüllbar 'realizable'
ergründbar 'penetrable/explicable'
ergründlich 'penetrable/explicable'
erheblich 'substantial'
Erholung 'recovery'
erkennbar 'recognizable'
erkenntlich 'grateful'
Erkrankung 'sickness'
erlernbar 'learnable'
Erlöser 'redeemer'
ermeßbar 'assessable/foreseeable'
Ermordung 'murder'
ermüdbar 'easy to tire'
Ernährer 'breadwinner'
Eroberer 'conqueror'
Erpresser 'blackmailer'
Erprobung 'trial/test'
erregbar 'excitable'
Erreger 'pathogen'
Erscheinung 'appearance/apparition'
erschließbar 'inferable'
erschöpfbar 'exhaustible'
erschöpflich 'exhaustible'
erschwinglich 'accessible/affordable'
ersetzbar 'replaceable'
ersetzlich 'replaceable'
ersichtlich 'apparent/evident'
ersinnlich 'conceivable/imaginable'
ertragbar 'bearable'
Erwartung 'expectation'
erweichbar 'that can be softened'
erweisbar 'demonstrable'
erweislich 'demonstrable'
Erwerber 'purchaser/acquirer'
Erzähler 'narrator'
Erzeuger 'creator'
erziehbar 'educable'
Erzieher 'educator'
Verachtung 'disdain'
Verarmung 'impoverishment'
Verbannung 'banishment/exile'
Verbauung 'control structure'
Verbeugung 'bow/curtsy'
Verbildung 'miseducation/deformation'
verbindlich 'binding'
Verblendung 'delusion'
Verblödung 'mental emfeeblement'
Verblutung 'exsanguination'
Verbraucher 'consumer'
Verbrecher 'criminal'
Verbreiter 'circulator'
verbrennbar 'combustible'
Verbuchung 'booking'
Verdammung 'condemnation'
Verdampfung 'evaporation/vaporization'

verderblich ‘perishable’
Verdichter ‘compressor’
Verdickung ‘thickening’
verdienstlich ‘meritorious’
Verdrehung ‘twist/contortion’
Verdunklung ‘darkening’
Verehrung ‘reverence/admiration’
Vereisung ‘glaciation/frosting’
vererblich ‘heritable/hereditary’
Verfasser ‘author’
Verfechter ‘advocate’
Verfehlung ‘offence/transgression’
Verfilmung ‘filming’
Verfolgung ‘tracking/prosecution’
Verführer ‘seducer’
Vergiftung ‘poisoning’
vergleichbar ‘comparable’
Vergottung ‘deification’
Verhaltung ‘retention’
Verhütung ‘contraception’
Verkehrung ‘reversal’
Verkennung ‘misjudgement’
Verkettung ‘concatenation’
Verkühlung ‘cold’
Vermahnung ‘admonition’
vermeidbar ‘evitable’
Vermessung ‘measurement’
Vermieter ‘landlord’
Vermischung ‘blending’
vermutlich ‘presumable’
vernehmbar ‘perceptible’
vernehmlich ‘audible/distinct’
Verneigung ‘bow/curtsy’
Verneinung ‘denial’
Vernichtung ‘extermination’
Verpflanzung ‘transplant’
Verpflegung ‘catering/board’
Verpflichtung ‘obligation/commitment’
Versager ‘failure (person)’
Versammlung ‘assembly’
Verschiffung ‘shipment’
Verschmutzung ‘pollution’
Verschönung ‘enhancement (of beauty)’
Verschreibung ‘prescription’
Verschuldung ‘indebtedness’
Versendung ‘dispatch/shipment’
versenkbar ‘lowerable/retractable’
Versorgung ‘maintainance’
Verspätung ‘delay’
Versprecher ‘slip of the tongue/Freudian slip’
Verstopfung ‘obstruction’
Versuchung ‘temptation’
Vertagung ‘adjournament/postponement’
vertauschbar ‘exchangeable’
Verteiler ‘distributor/distribution list’
Vertiefung ‘deepening’
Vertilgung ‘distruction/extermination’
vertraulich ‘confidential’
vertretbar ‘defensible’
Vertreter ‘representative/agent’
verwertbar ‘usable’
Verzeichnung ‘registering/distortion’
verzinsbar ‘bearing interest’
verzinslich ‘bearing interest’

7. General Discussion

Experimental research on morphology has long focused on the notion of 'morphological decomposition', the fundamental mechanism underlying the processing of complex words (e.g. Taft & Forster, 1975). According to the major accounts of morphological decomposition – i.e. *affix stripping* (Rastle et al., 2004; Taft & Forster, 1975), *edge-aligned embedded word activation* (Grainger & Beyersmann, 2017), and *single-route full decomposition* (Stockall & Marantz, 2006) –, this is a universal mechanism operating efficiently on all types of complex words irrespective of their characteristics. The former two accounts focus on visual word processing and postulate that morphological decomposition operates based on the surface form of words. According to the affix stripping account, all words that are decomposable into potential morphemes, even pseudo-complex words (e.g. *corner*), undergo morphological decomposition during the very early stages of processing. Instead, the edge-aligned embedded word activation account postulates that morphological decomposition is in fact a mechanism of extraction of embedded words from longer letter strings, irrespective of morphological complexity (thus operating even on words like *scandal*, thereby extracting *scan*). The latter account, single-route full decomposition, looks at morphology from a more abstract perspective and postulates that all words that can be decomposed into abstract morphemes will undergo morphological decomposition, irrespective of whether their surface form is segmentable into units (i.e. operating even on *sang*, decomposing it into the two abstract morphemes 'sing' and 'past-tense').

All the three accounts, despite their different approaches, would predict that the different position of stem and affix in prefixed and suffixed words (cf. *prepay* vs. *payer*) should also make no difference in how these are processed. However, studies on morphological decomposition have almost exclusively focused on suffixed words and on compound words, while prefixed words have been comparably neglected. For this reason, current theories of the mechanisms of morphological decomposition are under-determined. Against this background, the present dissertation provided an examination of prefixed words and of the factors that may influence how they are processed and impaired.

The work of the present dissertation was inspired by a framework proposed by Jakobson (1941–1968), who examined the relationship between language universals, language acquisition, and language loss. Jakobson (1941–1968) successfully managed to show that these three domains are strictly linked with each other, so that the linguistic phenomena that are cross-linguistically less widespread are also acquired later in language acquisition and more affected in language loss. His work focused on detecting correlations between these domains, without committing to effects of causation from one aspect onto the other, but rather proposing a framework that can be applied to the investigation of other linguistic phenomena than what he originally investigated (phonological oppositions).

The starting point of the thesis was a universal characteristic of morphological phenomena across the world's languages, i.e. the evidence that prefixing morphology is cross-linguistically less widespread than suffixing morphology (e.g. Greenberg, 1963). Starting from this observation, I then investigated how prefixed words are processed – thus extending Jakobson's approach from the domain of language *acquisition* to the domain of language *processing* (see e.g. Fodor, 1998) – in both (i) native and (ii) non-native visual word recognition, and how prefixed words are impaired (iii) in acquired language impairments, specifically in reading aloud.

There are two major accounts that have been proposed to explain the cross-linguistic preference for suffixation, namely the *processing* account by Cutler et al. (1985) and the *learnability* account by St. Clair et al. (2009). What the two accounts have in common is that they tried to establish relationships of causation between the cross-linguistic preference for suffixation and other domains, so that the former is the *result* of, respectively, processing and learning mechanisms which favor suffixed over prefixed words (see section 1.1. 'Prefixed words and the suffixing preference').

Based on the two major accounts of the suffixing preference, asymmetries in how prefixed words are processed in native and non-native speakers and in how they are affected in language loss may be predicted, which goes against the predictions of the three major accounts of morphological decomposition. The present dissertation thus contributes to reducing the gap between the current evidence for morphological decomposition and the accounts of the suffixing preference.

Because the accounts of morphological decomposition are mostly based on evidence from suffixed words and compounds, the first step to closing this gap is testing whether previous findings on suffixed words can be extended to the domain of prefixed words. I thus investigated morphological decomposition of prefixed words by pursuing the same research questions that have been tested in the research on suffixed words, both in the domain of (i) native and (ii) non-native morphological processing and in the domain of (iii) acquired morphological impairments. In addition to this, I then provided direct comparisons between prefixed words and suffixed words for all three domains. For the processing studies, I specifically focused on the *early stages* of visual word recognition tapped into by the masked priming technique, i.e. on access-level, modality specific, representations of complex words (Marslen-Wilson, 2007). For the studies on language loss, instead, I analyzed the errors produced in reading aloud tasks by speakers with acquired reading impairments, as a window on how complex words are represented in the mental lexicon, possibly tapping into *later* stages of processing (Luzzatti et al., 2001), although this technique does not allow us to be as precise as masked priming with regard to the specific stage of processing that we tap into. Hence, the two lines of research I pursued in the present thesis are informative with respect to different levels of the language system. The quality of the data obtained from the two techniques is also different: while psycholinguistic studies involve groups of speakers and draw inferences based on the average performance of a group, studies on morphological impairments have traditionally focused on case series or case studies, with the assumption that, because the language system is constant across all speakers, even the impairment of a single individual is informative about how the language system works and must be accounted for in models of the mental lexicon (Coltheart, 2001).

Table 1 summarizes the research questions that guided the present dissertation, which I presented in the Introduction (1.3 'Aims and objectives'), and the main findings from the four publications. Overall, we found evidence for efficient decomposition of prefixed words in the early stages of visual word recognition, for all types of prefixed words we tested, i.e. lexically restricted and unrestricted prefixed derivations as well as prefixed inflected words. Our results also suggest that non-native speakers can decompose prefixed derived words as efficiently as native speakers. We additionally found that prefixes can be more severely affected than suffixes, and we reported evidence of genuinely morphological errors with prefixes. In the next paragraphs, I will discuss the findings concerning each research question in detail and discuss their implications for models of morphological processing as well as for the assumed links between language universals, language processing, and language loss.

Table 1. Summary of the dissertation's research questions and main findings.

Research Question				Answer	Main Finding	Publication
1	Is morphological decomposition of prefixed words constrained by a word's specific linguistic properties?	1a	Does morphological decomposition work as efficiently for prefixed derived words as for suffixed derived words, in both lexically unrestricted and lexically restricted derivations?	YES	Significant priming effects, of similar magnitude, with prefixed and suffixed derived words, both lexically restricted and unrestricted	I
		1b	Are prefixed inflected words decomposed as efficiently as prefixed derived words?	YES	Significant priming effects with both prefixed inflected and prefixed derived primes, of similar magnitude	II
2	Can prefixed derived words be decomposed as efficiently in non-native processing as in native processing?			YES	Significant priming effects with prefixed derived words, both lexically unrestricted and restricted, in the L2 group, similar in magnitude to the L1 group	I
3	Are prefixed and suffixed words affected in different ways in acquired morphological impairments?	3a	Do the number and types of errors produced with prefixed words differ from those produced with suffixed words?	YES	More errors or more omissions with prefixes compared to suffixes	III, IV
		3b	Are morphological errors produced with prefixed words distinguishable from visual errors?	YES	Prefixes are generally omitted; non-morphological word beginnings are more often substituted with non-lexical strings (neologisms)	IV

7.1 Constraints on the processing of prefixed words

The first question I investigated concerned, broadly speaking, how prefixed words are processed in native processing. This was investigated with specific reference to the early stages of visual word recognition that are tapped into by the masked priming technique. In two different studies, I investigated whether the efficacy of morphological decomposition of prefixed words is affected by a word's specific linguistic properties. I specifically compared lexically restricted to lexically unrestricted prefixed derivations in Publication I, and prefixed inflected to prefixed derived words in Publication II.

In Publication I, we reported significant priming effects for both lexically unrestricted (e.g. *unsauber* [un-][sauber] 'not clean') and lexically restricted (e.g. *inaktiv* [in-][aktiv] 'inactive') German prefixed derived words. This suggests that, in the processing stages tapped into by masked priming, both types of prefixed derived words can be successfully decomposed into their constituent morphemes. Note that analogous results were found for the corresponding suffixed primes (*Sauberkeit* [sauber][-keit] 'cleanness' and *Aktivität* [aktiv][-ität] 'activity'), with no differences in the priming magnitude with prefixed and suffixed primes. These findings are in line with previous results on suffixed derived words, particularly with a previous study on English by Silva and Clahsen (2008) that reported significant masked priming effects with both *-ity* and *-ness* derivations (e.g. *acidity* and *firmness*) – respectively, lexically restricted and unrestricted.

In Publication II, we showed significant priming effects for prefixed inflected words in the Bantu language Setswana. Priming effects obtained with prefixed inflected words (e.g. *dikgeleke* [di-][kgeleke] 'experts') were similar in magnitude to those obtained with prefixed derived words (e.g. *bokgeleke* [bo-][kgeleke] 'talent'), on the same targets (e.g. *kgeleke* 'expert'). Investigating Setswana not only did allow extending previous claims on morphological decomposition to an under-researched language, but it also offered the unique opportunity to test prefixed inflected words, which are otherwise virtually absent from the most researched languages (generally Indo-European languages). Again, these effects are suggestive of efficient morphological decomposition for both inflected and derived words during the early stages of visual word recognition. These results extend previous results on suffixed words with native speakers, especially the study on German by Jacob et al. (2018), which tested inflectional and derivational priming on the same targets. Note that, in an additional set of items testing morphological priming effects with suffixed inflected words (with the past-tense suffix *-ile*, e.g. *supile* [sup][-ile] 'showed' – *supa* 'to show') and suffixed derived words (with the stative-formation suffix *-ega*, e.g. *supega* [sup][-ega] 'proven' – *supa* 'to show'), we only found numerical tendencies towards priming, which were not significant. Although this was not the main focus of the study, this is an unexpected result that needs to be accounted for. Because this finding may have to do with language proficiency, I will come back to it in the paragraph 'Morphological decomposition in an L2' (in 7.2 'Non-native processing of prefixed words').

Overall, the results of the two publications indicate that morphological decomposition of prefixed words in native speakers is robust, at least for the specific stage of visual word processing that I investigated. This replicates previous masked priming results on prefixed words (e.g. Diependaele et al., 2009; Kazanina, 2011; Mousikou & Schroeder, 2019) and, crucially, contributes evidence from morphological phenomena that were previously undocumented in the literature.

Models of morphological processing

Our results on prefixed words are in line with all major models of morphological decomposition, i.e. *affix stripping* (Rastle et al., 2004; Taft & Forster, 1975), *edge-aligned embedded word activation* (Grainger & Beyersmann, 2017), and *single-route full decomposition* (Stockall & Marantz, 2006), which would all predict, although with different explanations, efficient morphological decomposition for the prefixed items we tested in the present dissertation, such as the lexically restricted derivation *inaktiv* 'inactive' and the prefixed inflected word *dikgeleke* 'experts'. The affix stripping account claims that decomposition occurs for all words that can be segmented into a potential stem and a potential affix (hence, even pseudo-complex words such as *corner* [corn][-er]). Indeed, all prefixed items we tested in Publication I and II contained overt affixes and were segmentable into stem and affix. The edge-aligned embedded word activation account posits that embedded stems are always efficiently extracted at both word edges, even in the absence of affixes (such as *scan* in *scandal*). Again, the stems of the prefixed words we tested were entirely contained in the prefixed primes, so that our results can be explained by this account, too. Finally, the single-route full decomposition account claims that complex words are decomposed into their abstract morphemes based on grammatical rules. For all prefixes used in the present dissertation, we can identify a rule based on which the prefixed word is obtained from its stem: the derivational prefixes *in-* and *un-* included in Publication I are used to derive a negated form of their stems, while, in Publication II, the inflectional prefix *di-* marks the plural of the stem, and the derivational prefix *bo-* is used to derive an abstract noun from the stem.

At the same time, however, all models fail to explain the reduced priming effects for some types of morphologically complex items that have been reported in previous literature, such as the reduced priming effects for inflected words compared to derived words, yet only reported in non-native speakers (Jacob et al., 2018; Kirkici & Clahsen, 2013; Silva & Clahsen, 2008), and the reduced priming effects for lexically restricted (i.e. irregularly) inflected words (Morris & Stockall, 2012; Neubauer & Clahsen, 2009; Pastizzo & Feldman, 2002; Rastle et al., 2015). In Publication I, we proposed an account of morphological processing which was adapted and extended from the edge-aligned embedded word activation account by Grainger and Beyersmann (2017). Linguistic accounts of word formation have proposed that both stems and derivational affixes are lexical units, the only difference being that the latter cannot occur on their own but need to be attached to other stems (see e.g. Lieber, 1992; Selkirk, 1986). We proposed that the fact that a complex word is fully decomposable into lexical units, or 'lexemes', irrespective of whether these are stems or derivational affixes, causes an extra boost in the activation of its component morphemes. This boost in activation then explains why morphological decomposition of derived words, be it prefixed or suffixed, as well as of compound words, is particularly robust. This would *not* apply to the case of inflected words, which consist of a stem plus an inflectional affix, i.e. is a bundle of grammatical features (see e.g. Anderson, 1992), and are therefore not fully decomposable into lexical units. We may call this account *embedded lexeme activation*. The idea of an extra boost in activation of the component morphemes in case of full decomposability of the complex word is indeed already present in the account by Grainger and Beyersmann (2017), who use this notion to explain why a pseudo-complex word like *corner* primes *corn* but *scandal* does not prime *scan*. However, the account by Grainger and Beyersmann (2017) does not explicitly consider inflectional processes and their specific properties. Instead, our account distinguishes between two different outputs of morphological decomposition: the case in which words are fully parsed into lexical units, and the case in which decomposition results in a stem plus an affix encoding bundles of grammatical features. Morphological decomposition can operate in both cases, but, in the case of derived words, it will be more robust. In Figure 1, I visually represent the embedded lexeme activation account into an updated model of morphological decomposition in the early stages of processing, adapted and extended from Grainger and Beyersmann (2017).

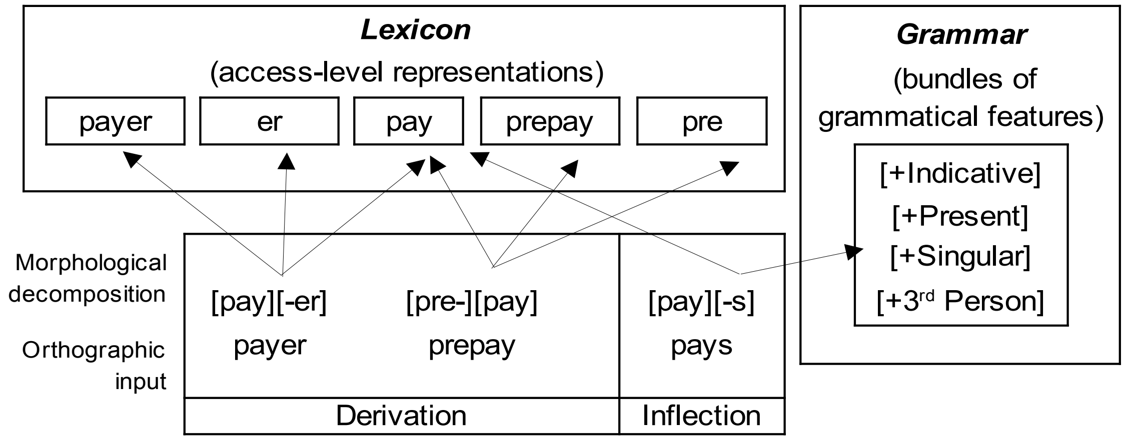

Figure I. Representation of the 'embedded lexeme activation' account.

Let us now focus on how the embedded lexeme activation account fares with the results of Publication I and II. Figure II illustrates the account again, this time with examples of the prefixed items used in the two publications. In Publication I, all the German words we tested were derived, and therefore fully decomposable into lexical units: decomposition of the lexically restricted prefixed word ***inaktiv*** 'inactive' results in the lexical units *in-* and *aktiv*, which would boost activation of both components, resulting in efficient morphological priming effects. This would be true for all other types of derived words we tested, e.g. the lexically unrestricted prefixed word ***unsauber*** [un-][sauber] 'not clean' and the lexically restricted and unrestricted suffixed words *Aktivität* [aktiv][-ität] 'activity' and *Sauberkeit* [sauber][-keit] 'cleanness'. As for Publication II, full decomposition into lexemes would apply to the prefixed derived Setswana words, e.g.

bokgeleke [bo-][kgeleke] 'talent'. Instead, decomposition of prefixed inflected words such as *dikgeleke* [di-][kgeleke] 'experts' results in activation of a stem (*kgeleke* 'expert') and of a bundle of features (e.g. [+plural]). As mentioned above, morphological decomposition and therefore stem activation can also work efficiently in the case of inflected words, which would explain the significant masked priming effects in this condition, indistinguishable from priming effects with prefixed derived primes.

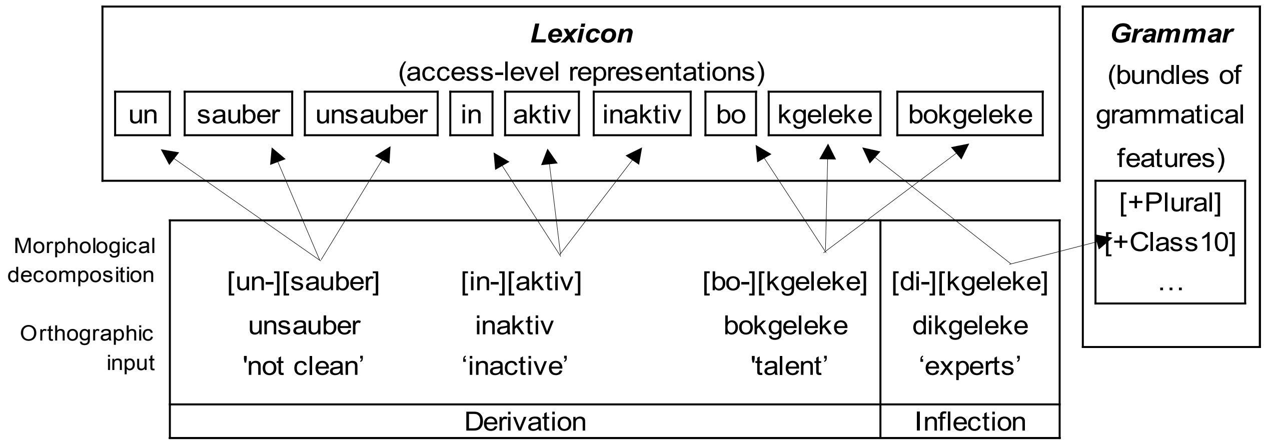

Figure 2. The 'embedded lexeme activation' account, with examples taken from the prefixed words tested in Publication I and II.

By positing distinct mechanisms for the decomposition of inflected and derived words, this model can account for the results on prefixed words of the present dissertation equally well as previous models, but it can additionally explain a larger number of studies from the morphological processing literature, i.e. those reporting reduced priming effects for lexically restricted inflectional, but not derivational, morphological processes, and those reporting reduced priming effects for inflection, but not for derivation, in L2 speakers (e.g. Jacob et al., 2018; Neubauer & Clahsen, 2009).

When would then morphological decomposition fail or be less efficient? As we suggested in Publication I, morphological decomposition fails when the inflectional rules needed to map an inflectional affix (in Figure 1, /s/) to the corresponding set of features are not fully operative, thus not allowing pre-activation of the stem (i.e. the target word). This would apply to irregular inflection, i.e. exceptional cases in which there is no clear rule-based relationship between the stem and its inflected form, and to L2 processing of inflection, as late L2 speakers may have weaker paradigmatic representations. At the same time, when such rules *are* fully operative, there is no reason why morphological decomposition through this route should not work efficiently. This explains not only the consistent evidence for significant masked priming effects with regularly inflected primes in native speakers (e.g. Jacob et al., 2018; Kielar, Joanisse, & Hare, 2008), but also the results with the Setswana inflected prefixed primes in Publication II. Since the participants were all native speakers of Setswana (despite the reduced language use in writing, a domain in which Setswana is subordinate to English) and since the type of plural inflection we tested was regular, there is no reason to believe that, in this case, the rule mapping from the plural prefix *di-* to its corresponding set of features should not be operative. Therefore there is significant priming with inflected primes, in line with previous results with regularly inflected suffixed words in native speakers.

A disadvantage for prefixed words in native processing?

By applying the approach proposed by Jakobson (1941–1968) to the investigation of morphologically complex words, and additionally extending it from the domain of language *acquisition* to the domain of language *processing*, we may predict a processing disadvantage for less widespread morphological phenomena, such as prefixed words, as compared to more widespread phenomena, such as suffixed words. Indeed, the processing account of the cross-linguistic suffixing preference by Cutler et al. (1985)

explicitly postulates that prefixed words are less widespread *because* they are more difficult to process. This would be due to the word-final position of the stem, because, according Cutler et al. (1985), processing a complex words is easier when its lexically most salient part, i.e. the stem, occurs word-initially and can thus be processed before the affix. We may therefore expect that early morphological decomposition of prefixed words would not work as efficiently as for suffixed words.

However, our finding of significant priming effects with prefixed words suggest that morphological decomposition works efficiently, leading to pre-activation of the stem. Our results are in line with with previous studies testing stem priming effects with prefixed primes (Diependaele et al., 2009; Kazanina, 2011; Kgolo & Eisenbeiss, 2015; Kim et al., 2015; Mousikou & Schroeder, 2019), but also go beyond previous research by providing evidence from previously undocumented phenomena, namely prefixed lexically restricted derivations and prefixed inflected words. Furthermore, of the previous masked priming studies testing prefixation, Diependaele et al. (2009), Kazanina (2011), and Kgolo and Eisenbeiss (2015) tested only prefixed words, but did not test suffixed words. The two studies by Kim et al. (2015) and Mousikou and Schroeder (2019), instead, reported significant priming effects with both prefixed and suffixed primes, but priming effects with prefixed and suffixed primes were tested in two different participant groups in the study by Kim et al. (2015), and with different target words in the study by Mousikou and Schroeder (2019). An additional advantage of the design of Publication I is that it allowed for a *direct* comparison of morphological priming effects with prefixed words to priming effects with suffixed words, which were tested *on the same targets* and *in the same participant group* for the first time in the literature.

Therefore, our finding of equivalent priming effects for prefixed and suffixed words does not support the idea that, for the stages of word recognition tapped into by masked priming, there is a processing disadvantage for prefixed words. Instead, prefixed words, in native processing, can be fully decomposed irrespective of their characteristics, i.e. irrespective of whether they are lexically restricted or unrestricted derivations, or whether they are inflected or derived words, and this seems to work as efficiently as for suffixed words.

The finding of comparably efficient morphological decomposition for prefixed and suffixed words is not in line with studies from other domains and using other experimental techniques. First, several studies on auditory word recognition (Meunier & Segui, 2003; Schriefers et al., 1991; Tyler et al., 1988) found evidence that prefixed words are not accessed through their stems, but rather as full forms, which would speak against morphological decomposition. Because, in the auditory domain, recognition is obligatorily constrained by the serial order in which sounds occur, this result is not very surprising. Hence, we may just explain the discrepancy between the studies from the auditory domain and the masked priming studies, including Publication I and II, by assuming that serial processing does not apply to visual word recognition. However, evidence for more effortful stem access in prefixed words, as compared to suffixed words, was also reported for the visual domain, namely in visual word recognition studies measuring unprimed lexical decision latencies and eye-fixation durations during reading (Beauvillain, 1996; Bergman et al., 1988; Colé et al., 1989; Ferrari Bridgers & Kacinik, 2017). The question is therefore how these results are compatible with the masked priming results. I will discuss this issue in section 7.4. 'An evaluation of the accounts of suffixing preference'.

7.2. Non-native processing of prefixed words

The second question I investigated in the present thesis was whether morphological decomposition of prefixed derived words in non-native processing works as efficiently as in native processing. This was investigated in Publication I, by comparing the priming effects obtained with prefixed derived words, both lexically restricted and unrestricted, in a group of non-native speakers of German to those obtained in a group of German native speakers. Again, the processing stages we specifically tested were the early stages of visual word recognition which are tapped into by the masked priming technique.

Our results from the L2 group showed significant morphological priming effects with both lexically unrestricted (e.g. *unsauber* [un-][sauber] 'not clean') and lexically restricted (e.g. *inaktiv* [in-][aktiv] 'inactive') German prefixed derived words, which were similar in size to the priming effects obtained in the L1 group. Prefixation priming effects in the L2 group also did not differ from the priming effects obtained with suffixed derivations, lexically restricted and unrestricted (respectively, *Sauberkeit* [sauber][-keit] 'cleanness' and *Aktivität* [aktiv][-ität] 'activity'), priming the same targets. Specifically important for the L2 group was also testing morphological priming effects against effects of bare orthographic overlap, to assess whether the former can be distinguished from the latter (see Heyer & Clahsen, 2015). We found that morphological priming effects were significantly larger than orthographic priming effects, both with prefixed and with suffixed primes.

The findings from the L2 group in Publication I indicate efficient morphological decomposition of prefixed derived words in L2 processing, extending previous evidence with suffixed words (e.g. Jacob et al., 2018; Diependaele et al., 2011), and particularly the results by Silva and Clahsen (2008) on lexically restricted (e.g. *acidity*) and unrestricted (e.g. *firmness*) suffixed derivations in English, to the domain of prefixed words. Instead, our results were not in line with previous L2 research that found masked morphological priming effects to be indistinguishable from orthographic priming effects (e.g. Heyer & Clahsen, 2015), especially the only study that investigated prefixed words in L2 speakers (J. Li & Taft, 2019).

Morphological decomposition in an L2

A substantial number of studies in the L2 masked-priming literature have provided evidence for less efficient morphological decomposition in L2 speakers compared to L1 speakers, during the early stages of visual word recognition (e.g. Jacob et al., 2018; Kirkici & Clahsen, 2013; Neubauer & Clahsen, 2009; Silva & Clahsen, 2008). This was taken to suggest that language status (i.e. being a native or non-native speaker of a language) can have an effect on how efficiently morphological decomposition operates. However, the L1-L2 contrast has only been found to apply to the case of *inflected* words, while, for derived words, masked priming studies have consistently shown significant priming effects in L2, parallel to L1, even in the same participants that showed no priming for inflection (Jacob et al., 2018; Kirkici & Clahsen, 2013). Note that all these studies exclusively tested the case of suffixed words. A relevant question for the domain of L2 processing is then whether decomposition of *derived* words in an L2 is always efficient, or, instead, there are cases in which it would fail or be at least less efficient than in native processing. In this respect, the results of Publication I represent an important contribution to the L2 morphological processing literature. First, it adds evidence for successful morphological decomposition of prefixed words, additionally comparing priming with prefixed words to priming with suffixed words, on the same targets. This is indeed novel, as the only study testing prefixed words in L2 processing (J. Li & Taft, 2019) did not compare prefixation priming to suffixation priming. Second, it also specifically tested priming in two types of derivations, lexically restricted and unrestricted. The fact that we reported significant priming effects in the L2 group even with prefixed words, whose decomposition has been claimed to be more effortful, and even with lexically restricted prefixations, further strengthens the idea that morphological decomposition of derived words is particularly robust. This indicates once again that the failure to decompose inflected words in an L2 observed in other studies does not have to do with a weaker ability to decompose morphologically complex words overall, but must necessarily pertain a selective difficulty with inflected words. Again, the results from the present dissertation and from recent L2 literature nicely fit the predictions of the embedded lexeme activation account described above. For a discussion of selective L2 difficulty with inflection, which – because I did not test inflected forms in L2 – is beyond the scope of the present dissertation, see Bosch, Veríssimo, and Clahsen (2019) and Veríssimo, Heyer, Jacob, and Clahsen (2018).

Another current issue in L2 morphological processing is whether masked morphological priming effects in L2 are distinguishable from orthographic priming effects. Masked morphological priming effects in native speakers have been convincingly shown to be distinguishable from any effect of form-level orthographic overlap, i.e. from priming effects tested in pairs such as *scandal-scan* (see Rastle et al., 2004, 2000). Instead, as pointed out by Heyer and Clahsen (2015), this may not be the case for L2 speakers, whose masked morphological priming effects are often indistinguishable from form priming effects, and may therefore be orthographic in nature. In some previous work (Ciaccio & Jacob, 2019), we showed that facilitatory orthographic priming effects in L2 speakers even extend to the later stages of processing that are tapped into by the overt visual priming technique, in which L1 speakers generally show inhibitory effects for orthographic priming (Fiorentino et al., 2016; Rastle et al., 2000). Note that a larger reliance on surface-level form cues in L2 speakers than L1 speakers has been additionally observed in other types of studies, both in the visual domain (Altarriba & Mathis, 1997; Talamas, Kroll, & Dufour, 1999) and in the auditory domain (Qu, Cui, & Damian, 2018; Veivo & Järvikivi, 2013; Veivo, Järvikivi, Porretta, & Hyönä, 2016), as well as in at least one cross-modal morphological priming study (Basnight-Brown, Chen, Hua, Kostić, & Feldman, 2007).

Publication I contributes to this issue by showing that L2 morphological priming effects with both prefixed and suffixed words were larger than any effect of, respectively, word-final or word-initial overlap, which is indicative of genuine morphological effects that cannot be explained in terms of bare orthographic priming. This finding certainly does not resolve the issue in the L2 masked priming literature, which still presents large variability when it comes to orthographic priming. For example, the studies by Jacob et al. (2018) and Kirkici and Clahsen (2013) report significantly larger morphological than orthographic priming, although there were some numerical, non-significant tendencies for orthographic priming in the L2 group. In the study by Diependaele et al. (2011), orthographic priming in the L2 group was significant, but still significantly smaller than morphological priming. Heyer and Clahsen (2015), instead, report morphological and orthographic priming effects of similar magnitudes; similar findings are reported by Feldman et al. (2010), at least for some of the conditions, and by M. Li et al. (2017b), yet only for word-initial, and not for word-final overlap. The study on prefixed words by J. Li and Taft (2019) also found similar magnitude of morphological and orthographic priming. J. Li et al. (2017a), instead, found that morphological priming was statistically indistinguishable from orthographic priming in two L2 groups with different proficiency levels, yet the orthographic priming effect was significant only in the low proficiency group. The authors took these results to suggest that orthographic priming is modulated by the speakers' proficiency. Indeed, considering that orthographic priming effects have additionally been observed in a study on heritage speakers (Jacob & Kırkıcı, 2016), hence native speakers with limited language use, it is conceivable that the L1-L2 difference with regard to orthographic priming effects does not have to do with language status per se, but rather with language proficiency or language use. This would also explain why, in the Setswana speakers of Publication II, we found significant priming effects in the orthographic control set (though only for word-initial overlap). Because Setswana is subordinate to English when it comes to written language, the participants we tested, despite being native speakers, have relatively little access to written Setswana, unlike the native speakers that have been tested in the research on Indo-European languages (e.g. Rastle et al., 2004), who are used to reading in their native language.

Finally, the dynamics involved in orthographic priming may also explain the only result, from Publication II, that the embedded lexeme activation model cannot account for, namely the lack of significant priming with suffixed Setswana words. In this additional item set, the targets (e.g. *supa* 'to show') were not entirely embedded in their corresponding inflected (*supile* 'showed') and derived primes (*supega* 'proven'). Whether the target is fully embedded in the morphologically complex prime has been previously reported to be irrelevant for morphological decomposition (e.g. McCormick, Rastle, & Davis, 2008). However, if the amount of orthographic overlap plays a role for Setswana speakers, then we can also see why priming effects may be reduced, to the point that they become not significant, when the prime and target do not fully overlap. Note that similar results, with reduced priming effects when the target is not fully embedded in the prime, had been previously reported for Setswana speakers by Kgolo and Eisenbeiss (2015).

A disadvantage for prefixed words in L2 speakers?

The second domain that I investigated in the present thesis, inspired by the framework proposed by Jakobson (1941–1968), was how prefixed words are processed in non-native language processing. According to the learnability account by St. Clair et al. (2009), the cross-linguistic preference for suffixing over prefixing morphology is rooted in human learning mechanisms. This thesis finds support in studies on first language acquisition and artificial language learning showing that prefixes are more difficult to learn than suffixes (Clark, 2001; Kuczaj, 1979; Mithun, 1989; Slobin, 1973). When it comes to morphological processing, morphological decomposition effects have been shown to emerge later in language development for prefixed than suffixed words (Hasenäcker et al., 2017). Based on this and on the processing account by Cutler et al. (1985), I asked the question whether prefixed words are specifically more difficult to process in non-native speakers as compared to native speakers.

The results that we reported in Publication I for the L2 group suggest that L2 speakers can decompose prefixed words efficiently during the early stages of visual word recognition. Furthermore, the effects of morphological decomposition obtained with prefixed words are similar in magnitudes to those obtained with suffixed words, as well as to those obtained in the L1 group. Therefore, we have no reason to believe that the word-final position of the stem should make morphological processing more difficult for L2 speakers than L1 speakers, or that that the larger costs associated with learning prefixes compared to suffixes influence how efficiently prefixed words are decomposed in an L2.

Putting together previous findings on language learning and language processing in children with the evidence from the present thesis, we can conclude that, although human learning mechanisms may affect how affixed words are acquired in language acquisition and processed in children, so that prefixed words are learned later and can be efficiently decomposed later in language development than suffixed words, this does not seem to extend to the domain of L2 processing. Note that our L2 participants were all advanced speakers of German. If morphological priming effects in adult L2 speakers follow a similar developmental trajectory of that observed in children by Hasenäcker et al. (2017), we may find that less advanced speakers show reduced or no priming effects with prefixed words. However, what is important to stress is that being an L2 speaker does not prevent the ability to decompose prefixed derived words efficiently (and possibly as efficiently as native speakers), at least when an advanced level is attained.

7.3. Prefixed words in acquired language disorders

The third question I investigated in the present dissertation concerned how prefixed words are impaired in language loss. I first asked whether there are differences, in terms of error rates and types of errors, in the impairment of prefixed and suffixed words (Publication III and IV). I then investigated whether morphological errors with prefixed words are distinguishable from visual errors and can thus be considered genuinely morphological (Publication IV), in line with previous evidence on suffixed words (e.g. Rastle et al., 2006). The three individuals presented in the two papers suffered agrammatic aphasia and were shown to be impaired for reading aloud morphologically complex words in preliminary assessments. Nevertheless, as discussed in Publication III, their individual profiles differed to some extent. In what follows, however, I will focus on what can be concluded about the impairment of prefixed words, this being the focus of the present dissertation, and not so much on the specific impairment profiles of the single participants.

As an extension of Table 1, Table 2 provides a more detailed overview of the main findings from the two publications.

Table 2. Overview of the main findings of Publication III and IV.

	Finding	Participant	Publication
1	More errors with prefixed words than simple words	NN	III, IV (Exp. 1)
		SA	III
2	More errors with prefixed words than suffixed words	SA	III
3	Affixes more affected in prefixed words than in suffixed words:		
	- More affix errors with prefixes	NN	III
		SA	III
	- More omissions of prefixes	NN	IV (Exp. 2, 3)
4	More omissions of prefixes compared to non-morphological word beginnings	NN	IV (Exp. 2)

Publication III provided a direct comparison of errors in reading aloud prefixed and suffixed word in three German individuals with agrammatic aphasia (NN, LG, SA). We analyzed error rates, as well as errors specifically affecting affixes and stems. Concerning overall error rates, all three individuals showed different profiles. NN showed the typical pattern of morphological impairments (e.g. Semenza & Mondini, 2015), with more errors produced when reading aloud prefixed and suffixed words compared to simple words. Error rates were similar for prefixed and suffixed words. The number of errors produced by LG, instead, was unexpectedly similar in all three conditions. Finally, SA showed a dissociation between prefixed and suffixed words, in that she produced more errors with prefixed words than with both suffixed and simple words. As regards errors on affixes in prefixed versus suffixed words, we reported that errors were more likely to affect prefixes than suffixes in both NN and SA, while LG produced comparably few affix errors in both conditions. Errors on prefixes were mostly affix omissions. As for errors on stems, we did not report any relevant finding for the comparison between prefixed and suffixed words.

In Publication IV, NN participated in three additional reading aloud experiments. The aim was to further investigate the nature of morphological errors in prefixed words. In Experiment 1, we replicated the finding of a disadvantage for prefixed compared to simple words in terms of overall error rates. In Experiment 2, we found that morphological errors produced with prefixed words are distinguishable from errors produced with words containing word-final embedded stems ('final embedding' condition; e.g. *Barock* 'baroque' contains *Rock* 'skirt/rock music'), and that errors on prefixes, which were mostly omitted, also differed from errors produced with suffixes, which were exclusively substituted with other suffixes. In Experiment 3, we replicated the finding that prefixes were more often omitted, while suffixes were exclusively substituted, in a new set of derived words containing both a prefix and a suffix.

In the following section 'A characterization of the impairment of prefixed words', I will focus specifically of what we can learn about prefixed words in language loss from Publication III and IV. In the section 'A disadvantage for prefixed words in language loss?', I will then discuss differences in the impairment of prefixed and suffixed words.

A characterization of the impairment of prefixed words

A large body of studies on acquired language impairments has investigated how morphologically complex words are impaired, covering different morphological phenomena such as compound words and affixed words, both inflected and derived (for a review, see Semenza & Mondini, 2015). When it comes to affixed words, derived or inflected, most studies have exclusively tested the case of suffixed words (e.g. Funnell, 1987; Rastle et al., 2006), and the literature lacks a systematic investigation of how prefixed words are impaired. The few studies including sets of both prefixed and suffixed (derived) words (Hamilton & Coslett, 2008; Job & Sartori, 1984; Kay, 1988) did not directly match or compare the two types of derivations, while the only study specifically focusing on prefixed words (Semenza et al., 2002) did not test suffixed words, hence we do not know whether the same participants would show different results for prefixed and suffixed words.

There are three main characteristics of how affixed words are affected in morphological impairments, as resulting from investigations on suffixed words. The first characteristic is that, generally, more errors are produced with affixed words than with matched simple words (see Luzzatti et al., 2001 for reading aloud; but also Hamilton & Coslett, 2007 for writing; and Lorenz & Biedermann, 2015 for naming). Yet, specific types of affixed words can be selectively impaired, with other types of affixed words being spared (e.g. impaired suffixed inflected words and spared suffixed derived words; Miceli & Caramazza, 1988; Tyler & Cobb, 1987). The second characteristic is that morphological errors, i.e. errors that reflect the morphological structure of the stimuli, affect affixes rather than stems. This means that, in incorrect responses, the stem tends to be produced correctly, while the affix is substituted or omitted (e.g. *playful* → «play» or «player»; Rastle et al., 2006). This is especially the case for agrammatic aphasia as well as impaired reading in acquired dyslexias (e.g. Luzzatti et al., 2001), which makes it particularly relevant to investigate affixed words, derived or inflected, in these types of disorders. The third characteristic is that morphological errors can be considered to be genuinely morphological, in that they are distinguishable from visual errors produced on words that contain embedded stems without being truly morphologically complex (such as *cashew* or *corner*; Rastle et al., 2006; Hamilton & Coslett, 2008). For all these three points, the two publications on prefixed words in language loss of the present dissertation importantly contribute to establishing whether what has been previously reported for suffixed words also applies to prefixed words.

Considering overall error rates, the finding of more errors produced with prefixed words than matched simple items, which we reported for NN and SA, is in line with the definition of morphological impairments, and replicates previous evidence from studies including sets of prefixed words (Hamilton & Coslett, 2008; Job & Sartori, 1984; Kay, 1988). LG, instead, produced similar error rates with prefixed words and simple words (as well as with suffixed words), which suggests that, at least for reading derived words, his impairment is not morphological. Furthermore, while, for NN, error rates with prefixed and suffixed words were similar (this was consistent in both publications), SA produced overall more errors with prefixed words than with suffixed words, and her errors with suffixed and simple words did not differ significantly. This suggests that SA's morphological impairment selectively affects prefixed words, leaving suffixed words comparably spared. This is a novel finding for the literature on morphological impairments and indicates that dissociations can also be found *within* the domain of derivational morphology, and specifically for prefixed and suffixed derived words, and not only for derived words as compared to inflected words. As we will see below, this dissociation was due to a selective impairment of *prefixes* as compared to suffixes.

Let us now come to the second characteristic of the impairment of affixed words, i.e. that errors affect affixes rather than stems. Remarkably, the study by Semenza et al. (2002), which was the only previous study specifically focusing on prefixed words, found that the errors produced by two participants with agrammatic aphasia were more often errors on stems than on prefixes, in contrast with previous evidence on suffixed words. Although we did not test this statistically, by looking at the counts of errors involving stems and involving affixes in Publication III (Table 5, Publication III), we can see that the two participants for whom we found evidence of a morphological impairment (NN and SA) clearly produced larger numbers of errors on prefixes than on stems. This suggests that, in line with previous research on derived words, morphological impairments of prefixed derived words affect prefixes more strongly the stems. The finding by Semenza et al. (2002) may therefore be due to specific characteristics of the impairment of their individual participants, who may have an overall difficulty in retrieving stems rather than affixes, for any type of affixed words, or to the specific properties of the items included in their study: all prefixes included in their materials were existing prepositions of Slovenian, i.e. free morphemes, which is unusual for studies on derivation and makes their items possibly more similar to compound words.

Once we have established that morphological errors on prefixed words tend to involve prefixes rather than stems, at least in agrammatic aphasia, what remains to be clarified is whether these errors are genuinely morphological or can just be explained in terms of visual or semantic errors. Whether morphological errors with prefixed words can be considered to be genuinely morphological was unclear from previously published studies (e.g. Badecker & Caramazza, 1987; Castles et al., 1996). Therefore, I investigated this question in Publication IV (Experiment 2), with participant NN, by comparing the errors he produced with prefixed words and with words containing word-final embedded stems ('final embedding' condition: *Barock* 'baroque' [Rock] 'skirt/rock music'). We found that the number of morphological errors that NN produced in the prefixed and final embedding condition was similar: there was a comparable number of errors in which the stem (or embedded stem) was preserved while the affix (or non-morphological word beginning) was impaired, i.e. omitted or substituted. However, errors affecting prefixes and non-morphological word-beginnings were qualitatively different: prefixes were mostly omitted while non-morphological word beginnings were rather substituted with non-lexical letter strings, resulting in neologisms. We took this qualitatively different pattern to suggest that errors in the two conditions have different sources. In the case of items containing word-final embedded stems, errors can be described as visual. This means that, when the target word cannot be retrieved, another visually similar word is produced (such as in *shallow* → «sparrow»; Funnell, 2000). The fact that the stem was correctly produced a comparable number of times for final-embedding items and prefixed items speaks in favor of theories that stress the role of embedded stems in word processing (Grainger & Beyersmann, 2017; Hasenäcker, Solaja, & Crepaldi, 2020). Yet, crucially, the fact that a letter string (in this case, a non-existing letter string) was added to the embedded stem *only* for the items of the final embedding condition suggests that an attempt was made to retrieve a full form. This was not the case for prefixed words, as prefixes were significantly more often omitted, thereby only producing the stem. We therefore suggested that morphological errors with prefixed words are distinguishable from bare visual errors. Because NN never produced semantic errors (e.g. *wood* → «forest») throughout the whole experiment or in the preliminary assessments, his errors cannot be explained in terms of semantic errors either, and must be genuinely morphological.

As I will discuss in the next section, we also directly assessed how likely it was to produce errors specifically affecting prefixes as compared to suffixes. For this analysis, we reported, quite consistently across the two publications, that prefixes are generally more impaired than suffixes. In Publication III, we found larger numbers of errors specifically involving prefixes as compared to suffixes for two participants, NN and SA. Affix errors on prefixes were mostly omissions. In the third participant, LG, this pattern did not emerge, since he produced a similar (small) number of affix errors with both prefixes and suffixes; but note that, as underlined above and in Publication III, there was no evidence that his impairment is morphological in nature (at least for derived words). In Publication IV, NN produced a similar number of affix errors with prefixes and suffixes, but we reported a difference in terms of types of errors involving prefixes and suffixes:

suffixes were exclusively substituted with other existing suffixes, while prefixes were mostly omitted. The same result was found in two different experiments with different types of items.

The finding that prefixes are more impaired than suffixes in both SA and NN is important for two reasons. First, it shows that the selective impairment for prefixed words in the overall error rates reported for SA in Publication III is in fact due to a selective impairment of *prefixes*, and not of the prefixed word as a whole or of their stem. Second, it also shows that prefixes can be selectively more impaired than suffixes even when the overall error rates for prefixed and suffixed words are similar, as consistently reported for NN in both publications. I will further discuss differences between prefixed and suffixed words in the next section.

Findings on the impairment of prefixed words can be summarized as follows: (i) prefixed words yield more errors than simple words, and can also be selectively impaired, with comparably spared suffixed words; (ii) morphological errors with prefixed words affect the affix more than the stem, like in suffixed words; (iii) morphological errors with prefixed words are genuinely morphological; (iv) affixes are more affected in prefixed than in suffixed words.

A disadvantage for prefixed words in language loss?

Following Jakobson's (1941–1968) approach on the relationships between language universals, language acquisition, and language loss, I finally investigated the domain of acquired language impairments and asked the question whether prefixed words are impaired more heavily than suffixed words. The results of the present thesis indeed show that prefixed words can be significantly more affected by language loss than suffixed words. Therefore, the findings of the thesis suggest that the evidence provided by

Jakobson (1941–1968), specifically, in this case, for the relationship between language universals and language loss, would also apply to the domain of prefixing and suffixing morphology.

There are two main findings concerning differences in how prefixed and suffixed words are impaired. First, for SA, we reported a selective impairment for prefixed words in the *overall error rates*, with prefixed words yielding more errors overall than both simple and suffixed items. Our second finding was that, when specifically looking at the errors affecting *affixes*, we found that prefixes are more impaired than suffixes.

Let us start from the first effect that is reported, i.e. the selective impairment for prefixed words that we found in SA in Publication III. Recall that this analysis focused on overall error rates, without distinguishing for the specific types of errors produced (i.e. it included any kind of error, such as full-form errors, errors on affixes, and errors on stems). In Publication III, we originally explained this finding along the lines of what has been proposed by Cutler et al. (1985) and in some psycholinguistic studies (e.g. Ferrari Bridgers & Kacinik, 2017), i.e. in terms of larger processing costs for prefixed words due to more effortful stem access when this is in word-final position. However, the overall picture from the two publications rather suggests that this has to do with an impairment of retrieving affixes, rather than stems. First, if the selective impairment for prefixation found in SA was due to a difficulty in processing the stem, then this should have been reflected in the analysis of errors specifically focusing on stems that we performed in Publication III, yielding more errors on stems for prefixed words than suffixed words. Instead, no such difference was reported. Second, when looking more closely at the types of errors that are included in this overall count of error rates (Table 5 in Publication III), we can see that, if we subtract SA's number of affix errors with prefixed and suffixed words (25 affix errors with prefixed words, 4 with suffixed words) from the total number of errors in the two conditions (102 errors overall with prefixed words, 81 with suffixed words), the number of remaining errors in the two conditions is exactly the same (102 - 25 = 77; 81 - 4 = 77). This shows that SA's selective impairment for prefixed words is entirely caused by a selective impairment of *prefixes*. Therefore, this finding is in fact already included in the second finding, which is that, when specifically focusing on errors on affixes, prefixes tend to be more affected than suffixes.

Coming to the errors specifically affecting affixes, in Publication III, we found that both SA and NN produced more affix errors involving prefixes than suffixes. Errors on prefixes were mostly omissions. We then found, for NN, larger number of omissions for prefixes as compared to suffixes in Experiment 2 and 3 of Publication IV. Overall, the results from the two publications quite consistently suggest that, in morphological impairments, prefixes are more likely to be lost than suffixes, be it through the occurrence of more affix errors or through the occurrence more omissions of prefixes compared to suffixes.

A first question that this finding raises is what causes prefixes to be more impaired than suffixes. A possible explanation may be that this result is a bare effect of 'headedness'. In derived words, while the head of a prefixed word is generally the stem, the head of a suffixed word tends to be the suffix (Williams, 1981). Although there are exceptions to this general rule (see e.g. *enlarge* in English, in which the prefix *en-* transforms the base adjective *large* into a verb and is thus the grammatical head), this applies to most derived words. As pointed out in the Introduction, a well-known finding from studies on compound words in acquired language impairments is that head morphemes tend to be retained better than non-head morphemes (Marelli et al., 2013; Semenza, Arcara, et al., 2011). Therefore, a point that would need to be clarified is whether the effect we report is, in fact, only an effect of headedness, and hence would disappear if we only tested prefixed words with head prefixes. By exploring the numerical tendencies in the data of Publication III, it turned out that 21.7% (5/23) of NN's prefix errors and 24% (6/25) of SA's prefix errors were with head prefixes. This is a quite large number, considering that only 20% of the items contained a head prefix, and thus it seems to suggest that head prefixes can be equally impaired as non-head prefixes, and that the effect we reported here does not have to do with headedness.

I therefore suggest that, instead, the difference in the impairment of prefixes and suffixes we reported can be explained in terms of the function of affixes of specifying properties of the stem and of the preferred position that they should therefore occupy relative to the stem itself. St. Clair et al. (2009) claimed that it is easier to learn affixes when they follow the stem whose properties they specify than when they precede it, i.e. in the case of suffixes as compared to prefixes. This may then also lead to weaker representations of prefixes, i.e. less consolidated knowledge about the properties that they encode, making them more prone to being affected by language loss and therefore resulting in larger numbers of affix errors or of omissions with prefixes compared to suffixes.

A second question is then is to what extent this is compatible with the results from the masked priming results included in the present thesis, which showed parallel priming effects for all types of derived words. As noted in Publication III, the locus of the impairment of the language-impaired individuals we tested does not seem to be tied to morpho-orthographic processing in the input modality. Instead, their impairment possibly arises from later stages of processing in which lexical-semantic information of the constituents becomes available, as also assumed in similar studies by Marelli et al. (2012) and Rastle et al. (2006). This is a very different stage of processing from the early stage of visual word recognition tapped into by the masked priming technique, which explains the discrepancy between the masked priming results and the results on aphasia. I will come back to this point in section 7.4 'An evaluation of the accounts of the suffixing preference'.

In sum, our findings suggest that prefixed words are more affected by language loss than suffixed words, in line with the predictions derived from Jakobson's (1941–1968) account. An interesting question that remains open is to what extent what we report for acquired language impairments also applies to other types of language loss or attrition. For example, the hypothesis by Jakobson (1941–1968) has been discussed in several studies on first language attrition in emigrant populations (so-called 'heritage speakers'; e.g. Arslan, Bastiaanse, & Felser, 2015; Montrul, 2009), in which it is mostly referred to as the 'Regression Hypothesis'. Particularly relevant is the evidence suggesting that links between first language acquisition and first language attrition seem to exist for morphology (diminutive and plural inflection, tested in Dutch) but not for other domains (Keijzer, 2010), which raises the question about what would happen for prefixing versus suffixing morphology. Furthermore, performance with morphologically complex words can also be affected by healthy aging. Several studies have investigated this with reference to morphological processing in visual word recognition (e.g. Reifegerste & Clahsen, 2017; Reifegerste, Elin, & Clahsen, 2019). The question of whether there are differences between prefixed and suffixed words in language processing in older age is therefore relevant not only for the question originally formulated by Jakobson (1941–1968) on the relationships between first language acquisition and language loss or attrition, but also for current research on language processing in healthy aging.

7.4. AN EVALUATION OF THE ACCOUNTS OF THE SUFFIXING PREFERENCE

A final question that needs to be addressed is to what extent the two major accounts of the cross-linguistic suffixing preference, i.e. the processing account by Cutler et al. (1985) and the learnability account by St. Clair et al. (2009), find support in the data presented in the present dissertation and in previous evidence. Of the two accounts, the processing account has major implications for the research conducted in the present thesis, while the implications of learnability account on the work presented here are relatively secondary.

Starting from the *learnability* account by St. Clair et al. (2009), this predicts that prefixed words should be more difficult to learn. Indeed, this account has found support not only in studies investigating child language acquisition, but also in experiments testing language learning mechanisms through artificial language learning tasks (Clark, 2001; Kuczaj, 1979; Mithun, 1989; Slobin, 1973; St. Clair et al., 2009). This finding may then also extend to how prefixed words are learned in a second language. Yet, this is not what I tested in the present thesis. What this thesis investigated is, instead, how prefixed words are *processed* in an L2, specifically in the early stages of visual word recognition. Note that, because in the study on L2 processing (Publication I), we only tested prefixed *derived* words, the only conclusion that we can draw is about derivational morphology. For this domain, we reported efficient morphological decomposition of prefixed words in L2 speakers, with parallel results both for prefixed and suffixed words and for L1 and L2 speakers. Therefore, what we can conclude about this account from the present dissertation is that its predictions *do not* extend to the domain of L2 processing, at least for the early stages of the processing of derived words, but seem to be limited to the domain of language *learning*. Indeed, this account only makes reference to learning, without making claims on how words are processed once they have been acquired.

A relevant aspect from the learnability account was its focus on the role that affixes play in specifying the properties of stems. This turned out to be useful to explain the different pattern of impairment for prefixes and suffixes: if learning affixes is easier when these follow the stem whose properties they specify (suffixed words) than when they precede the stem (prefixed words), this can also lead to less consolidated representations of prefixes, making them more prone to being affected in language loss. I will come back to this point, and to the stage of processing for which this aspect becomes relevant, below.

Coming to the *processing* account by Cutler et al. (1985), the findings from the two masked priming experiments suggest efficient morphological decomposition of prefixed words, leading to successful pre-activation of the stem, with no evidence for a disadvantage for prefixed as compared to suffixed words. Therefore, the processing account does not find support in the masked priming results that I presented. While these results are in line with previous findings from the masked priming literature (e.g. Diependaele et al., 2009; Kazanina, 2011), they seem to be incompatible both with previous studies investigating visual word recognition using other techniques (Beauvillain, 1996; Bergman et al., 1988; Colé et al., 1989; Ferrari Bridgers & Kacinik, 2017) and with the results on aphasia presented here.

Let us first look at the previous studies on visual word recognition. The main finding of the study by Ferrari Bridgers and Kacinik (2017) are longer RTs for prefixed words compared to matched suffixed words. The main finding of the study by Bergman et al. (1988), instead, is that RTs to suffixed and pseudo-suffixed words are comparable, while RTs to pseudo-prefixed words are longer than RTs to prefixed words. Finally, Colé et al. (1989) found that cumulative root frequency affects RTs to suffixed words, but not RTs to prefixed words, while Beauvillain (1996) reported that, in prefixed words, root frequency only modulates later eye-tracking measures (second fixation durations), while it affects early measures (first fixation durations) in suffixed words.

First, note that Bergman et al. (1988), Colé et al. (1989), and Ferrari Bridgers and Kacinik (2017) used simple lexical decision tasks, which tap into later processes of visual word recognition than masked priming (see Baayen, 2014). Furthermore, when it comes to cumulative root frequency, manipulated by Colé et al. (1989) in lexical decision tasks and by Beauvillain (1996) for eye-fixation duration measures, this factor has been shown to have no effect for the processing stages tapped into by masked priming (Giraudo & Grainger, 2000). We can then conclude that all these studies tapped into different, later stages of visual word recognition than those that are tapped into by masked priming.

Therefore, the apparent contrast between the results from these studies and the findings from the masked priming literature, including those of the present dissertation, can be resolved by assuming that, in the very early stages of processing, complex words are fully parsed into their constituent morphemes following the 'embedded lexeme activation model' of the early stages of morphological decomposition, depicted in Figure 1 and 2. This is a stage of visual word recognition during which, according to our model, the processing system is sensitive to the distinction between lexemes (stems or derivational affixes) and bundles of grammatical features (inflectional affixes), but not to the distinction between stems and derivational affixes (although positional constraints may apply; see Crepaldi, Hemsworth, Davis, & Rastle, 2016). After this stage, the lexical-semantic information encoded by the different types of 'lexemes' come into play. The information encoded in the different constituents is processed, and the processing system needs to first identify the type of lexical-semantic information encoded in the stem. If the stem is the second constituent (prefixed words), this causes an increased processing cost as compared to a situation in which the stem is the first constituent (suffixed words), as originally suggested by Cutler et al. (1985).

This also means that the linguistic differences that do not affect morphological decomposition in early stages of visual word processing may, instead, affect access to stem information in later processing stages. For example, while both *inaktiv* 'inactive' and *unsauber* 'not clean' can be successfully decomposed in the stage of processing tapped into by masked priming, processing the information contained in the stem may be more challenging when this is preceded by the lexically restricted prefix *in-* compared to the unrestricted *un-*. In contrast, this should not apply to accessing the same stems *aktiv* and *sauber* when they occur word-initially, i.e. in *Aktivität* and *Sauberkeit*, as the lexically restricted and unrestricted affixes occur only after the information contained in the stem has been processed.

Concerning the results presented here on prefixed words on aphasia, the main finding was that the prefixes were consistently more impaired than suffixes. Considering that the individuals involved in the present thesis were significantly impaired for reading aloud non-words, reading aloud in their case can only occur through the lexical route and is therefore considered to be informative for how the mental lexicon works (e.g. Luzzatti et al., 2001). As noted in the previous section, the impairment of the participants we tested most likely arises from later stages of processing, in which the information encoded in the constituent morphemes is processed. At this stage, affixes containing less consolidated information about the properties of the stem that they encode will be more prone to being produced incorrectly or omitted, leading to larger numbers of affix errors or affix omissions with prefixes. Clearly, this difference between prefixes and suffixes can only surface in a stage of processing in which the information contained in the different morphemes is processed, while it has no impact on the early stages of visual word recognition tapped into by masked priming.

Note that explaining a processing disadvantage for prefixed words only focusing on the costs related to accessing the stem is not enough to explain our data, since the impairments we found in our participants specifically had to do with affixes. Putting together previous studies and the results from the present data on language loss, it seems that prefixed words, during later stages of processing, can present a disadvantage both because it is more effortful to process the information contained in the *stem* when this is in word-final position (previous psycholinguistic literature) and because it is more effortful to retain the information contained in an *affix* that precedes the stem whose properties it specifies (present studies on language impairments). Hence, future research should focus on both aspects.

To sum up, I have shown that, while the processing disadvantage postulated by Cutler et al. (1985) seem to hold for later processing stages during which lexical-semantic information comes into play, this account fails to capture the early stages of visual word recognition, during which prefixed words are processed equally efficiently as suffixed words. Hence, by using the masked priming technique to probe the account by Cutler et al. (1985), and by testing how prefixed words are impaired in language loss, we were able to constrain the implications of this account to later stages of processing.

On a more general level, a broader conclusion that can be drawn from the present thesis is that claiming for an overall 'processing disadvantage' to explain cross-linguistic language universals, without making reference to psycholinguistic models of language processing, leads to inaccurate descriptions. Instead, such accounts should carefully consider the different stages of processing that have been identified in psycholinguistic research and what factors come into play in each stage, to be able to formulate more precise predictions.

8. Concluding remarks, limitations, and future perspectives

Current accounts of how morphologically complex words are processed and impaired aim to provide a description of mechanisms that are assumed to operate universally for all types of morphologically complex words, irrespective of their specific properties. However, these accounts have mostly based their claims on evidence from suffixed or compound words, while prefixed words have been comparably neglected. At the same time, accounts of the cross-linguistic preference for suffixing over prefixing morphology would predict differences in how prefixed and suffixed words are processed, learned, and, possibly, lost. The present work aimed at reducing the gap between these two approaches by providing a thorough investigation of prefixed words in native and non-native language processing and in acquired language impairments. The thesis contributes to the current understanding of prefixed words in morphological processing and morphological impairments by addressing to what extent the findings that have been previously investigated for suffixed words also apply to prefixed words, and by additionally providing direct comparisons of prefixed and suffixed words.

Native and non-native processing of prefixed words was investigated with regard to the early stages of visual word recognition. The first conclusion that we can draw from the results of thesis is that morphological decomposition of prefixed words during the early stages of visual word recognition works as efficiently as for suffixed words. Effects of morphological decomposition were found for all the types of prefixed words that we investigated, i.e. lexically restricted and unrestricted prefixed derived words, as well as prefixed inflected words. Based on these findings and on previous evidence, I updated previous accounts of the early stages of morphological processing into an account labeled 'embedded lexeme activation', which postulates that morphological decomposition is also sensitive to the units into which complex words are decomposed. On the one hand, there are units that have lexical status on their own, i.e. stems and derivational affixes. On the other, there units that represent bundles of grammatical features, i.e. inflectional affixes. When the result of morphological decomposition are lexical units, e.g. two stems or a stem and a derivational affix, this mechanism works particularly robustly. Instead, when it results into a stem plus a bundle of grammatical features, there is evidence from previous literature showing that morphological decomposition may fail or be less efficient, in case the rules needed to map an inflection affix (such as *-ed*) to the corresponding features are not fully operative. The second conclusion that we can draw from the results of the thesis concerns the processing of derivation in a non-native language, for which we found that morphological decomposition works as efficiently as in native speakers not only with suffixed derived words, but also with prefixed derived words, which further strengthens the claim that decomposition of derived words works particularly robustly. I additionally showed that the embedded lexeme activation model is also able to capture this finding. Finally, concerning prefixed words in acquired language impairments, we can conclude that prefixes tend to be more affected than suffixes. This was taken to suggest that, in later stages of morphological processing, when the information encoded in the constituent morphemes is processed, differences between prefixes and suffixes become relevant. Because prefixes are more difficult to learn, this may lead to less consolidated representations of the properties of the stem that they encode, making them more prone to language loss.

The present dissertation thus clarifies several aspects of how prefixed words are processed and how they are affected by language impairments that were previously unclear or yet unexplored. At the same time, it also raises some new questions, opening the ground to future investigations. I will outline some of these in the following paragraphs, which conclude the thesis.

The 'embedded lexeme activation' account

One limitation of the updated account of the early stages of visual word recognition that I presented, the 'embedded lexeme activation' account, is that, in the current thesis, I only tested cases for which the model would predict efficient morphological decomposition, and therefore significant morphological priming effects under masked priming conditions. Our model does capture some cases in which morphological decomposition fails or would be less efficient, but these are are findings from previous literature (e.g. Jacob et al., 2018; Neubauer & Clahsen, 2009) and, additionally, they are only findings on suffixed words. Ideally, the picture would be complete if we added data from non-native speakers of a language with both inflectional and derivational prefixes. Clearly, because these languages are relatively rare and even more rarely learned as an L2, this remains an open challenge for future research. Another interesting way to test the predictions of the model would be to replicate the findings from Publication I with lexically restricted and unrestricted prefixed derived words in L2 speakers with another group of advanced non-native speakers whose L1 does not present with productive prefixation, such as Turkish (see e.g. Göksel & Kerslake, 2005). If, as the model predicts, early morphological decomposition of *derived* words always works robustly, then there should be no effect of the characteristics of the L1 on decomposition of derived words in an L2.

The masked priming results presented in the dissertation as well as those I reviewed to propose the embedded lexeme activation account all tested priming effects from shared *stems*. However, the model also makes predictions for priming effects from shared *affixes*. In the case of shared *derivational* affixes, for example in pairs such as *prepay-preview* or *player-worker*, our account would predict robust morphological priming effects, through activation of the corresponding lexical units (the derivational affix), in an analogous way as it occurs for shared stems. Indeed, previous literature shows consistent evidence for significant priming effects from shared derivational affixes, both prefixes and suffixes, even when the primes are affixes presented in isolation (e.g. Chateau et al., 2002; Crepaldi et al., 2016; Domínguez et al., 2010; Duñabeitia, Perea, & Carreiras, 2008; Giraudo & Grainger, 2003; Lázaro, Illera, & Sainz, 2016).

As for masked priming effects from shared *inflectional* affixes, such as in *played-worked*, the question is whether priming is at all possible, since it would arise through activation of a shared affix that is just a spell-out of grammatical rules. The only study investigating this (Smolìk, 2010), yet only for inflectional suffixes, indeed found inconclusive results. The account we proposed would predict at least more variability in priming from shared inflectional affixes as compared to shared derivational affixes, and that priming effects would possibly vary as a function of the amount of overlap in the features that the affix encodes. Some indication that this might be a promising direction comes from a recent study on German inflected adjectives (Bosch & Clahsen, 2016) showing that priming effects are significantly reduced in pairs of inflected adjectives such as *geheimem-geheime* ('secret'), but not for pairs such as *geheimes-geheime*; the difference between the two is that, in the former pair, the inflectional affix *-m* in the prime includes the feature 'oblique case' which mismatches with the inflectional affix *-e* in the target (since this cannot be used for the oblique case and is thus negatively marked for this feature), while the target in the latter pair does not contain features that mismatch with the prime. Although the study did not directly test priming from shared inflectional affixes, its results indicate that priming effects with inflected prime-target pairs vary as a function of the amount of overlap in the grammatical features that the affix encode, which is compatible with the predictions of the embedded lexeme activation model.

Variability in morphological processing

The present thesis investigated morphological processing of native and non-native speakers taken as whole groups. However, recent morphological processing studies have also focused on how the magnitude of priming effects in morphological priming experiments varies as a function of individual differences (Andrews & Lo, 2013; Beyersmann et al., 2015a, 2016; Hasenäcker, Beyersmann, & Schroeder, 2015; Veríssimo et al., 2018). While in Publication I we reported similar priming effects for prefixed and suffixed derived words, it may still be the case that priming with prefixed words is more susceptible to individual differences: the word-final position of the stem may affect the ability to decompose prefixed words only for *some* of the participants, and this may not be visible from standard group-level RT analyses. The embedded lexeme activation account predicts that morphological decomposition always works robustly for derived words, both prefixed and suffixed, while priming for inflected forms is more variable. Hence, finding that morphological decomposition is more susceptible to individual variability for prefixed derived words than for suffixed derived words would go against the predictions of our account.

Interestingly, none of the papers mentioned above reported effects of individual differences on priming with derived words. Andrews and Lo (2013) reported that the participants' individual profiles (whether they were better in spelling or vocabulary) modulated priming effects with pseudo-complex primes such as *corner* (in the pair *corner-corn*), but not with truly morphologically complex (derived) primes. Beyersmann et al. (2015a), instead, divided their participants into two groups based on a composite proficiency measure, and found that only highly proficient speakers showed priming effects for non-morphological pseudo-words such as **tristald* 'sadald' priming *triste* 'sad'; again, this measure did not modulate the priming effects with truly morphologically complex words. Similar effects are reported by Beyersmann et al. (2016) and by

Hasenäcker et al. (2015). Finally, in Veríssimo et al.'s (2018) study on bilingual speakers, the authors found that age of acquisition modulates priming with inflected words, but not with derived words. The good news is that the embedded lexeme activation account therefore finds support in the findings of all these papers, but the bad news is that none of them has investigated individual differences in priming with truly prefixed words, which remains open to future investigations.

Another way to investigate variability in different conditions, without necessarily focusing on inter-individual differences, is moving away from bare means and analyzing the whole RT distribution (see e.g. Balota, Yap, Cortese, & Watson, 2008). Standard group-level analyses of RT data have traditionally focused on mean RTs and looked at whether they differ for the different conditions. However, two conditions may have similar mean RTs, but their underlying RT distribution may still differ. For example, they may have different standard deviations, and hence different levels of variability around their central point. Hence, while prefixed and suffixed words may show similar priming magnitude, they may still differ in terms of the standard deviation around their mean RT. This represents yet another intriguing development for future investigations, which would also further test the validity of the account proposed in the thesis.

Item selection and item variability in morphological impairments

Finally, some limitations need to be acknowledged with regard to the items we tested in the two publications on morphological impairments. Performing analyses on individual participants requires collecting data from considerably more items than what one would normally include in psycholinguistic experiments looking at group-level analyses – especially considering that some of the analyses are performed only on the subset of incorrect responses. At the same, there are more variables that need to be matched across conditions compared to visual word recognition studies, especially the imageability of the stimuli and of their stems (see Funnell, 1987). Selecting a number of items that is reasonably large while controlling for all relevant variables represents an important challenge to a clean experimental design. This often leads to stimuli that contain several different affixes. In Publication III, for example, I gave priority to perfectly matching the items for word-class, since this is a fundamental variable in agrammatic aphasia (see Miceli, Silveri, Villa, & Caramazza, 1984). However, this implied also including verb suffixes, for which distinguishing between errors on the derivational suffix and on the verbal infinitival ending *-en* was not trivial. Also, the items in the different conditions varied especially in terms of the variety of affixes included in the different conditions, but also in terms of the presence of stem alternations. In Experiment 2 of Publication IV, the priority was the matching of items across conditions for stem and full-form imageability and frequency, to replicate the findings by Rastle et al. (2006). This, however, led to inconsistencies in the word-class of items across conditions which, although it can be added as covariate in the statistical models, is again suboptimal. Experiment 3 of Publication IV allowed more freedom in the selection of the items, since prefixes and suffixed were compared within the same three-morphemic words (e.g. *Entwertung* [ent-][wert][-ung] 'devaluation'). In this case, I could select a large number of items (200 derived words), while at the same time having similar distributions of the same prefixes and the same suffixes (i.e. there were four prefixes and four suffixes, each repeated for a comparable number of times).

Specifically concerning errors on affixes, De Bleser and Bayer (1990) reported that the types of errors affecting affixes vary as a function of the kind of information the affix encodes, so that, for example, affixes that have stronger semantic content such as the German negation prefix *un-* are paraphrased; instead, affixes that mostly serve syntactic functions, such as the German suffix *-lich*, used to derive adjectives from nouns, tend to be rather omitted. Despite the suboptimal aspects in the experimental designs discussed above, it is encouraging to observe that the finding we reported for affix errors was the most consistent across the two publications: more errors on prefixes than on suffixes for SA and NN in Publication III, with errors on prefixes being mostly omissions; more omissions of prefixes than suffixes in Experiment 2 of Publication IV and again, in Experiment 3. Furthermore, when analyzing, with exploratory purposes, a sub-set of prefixed and suffixed items with homogeneous semantic content (the negation prefix *un-* and the negation suffix *-los*) in Publication III, results seemed to go in the same direction as for the full set of items. However, in future research, it would be relevant to follow up on the findings about item-level variability by De Bleser and Bayer (1990) and bridge them to the findings of the present dissertation, to ascertain to what extent the specific affix characteristics – e.g. their meaning or productivity – interact with the differences between prefixes and suffixes that I reported.

References

Abrahantes, J. C., & Aerts, M. (2012). A solution to separation for clustered binary data. *Statistical Modelling: An International Journal, 12*(1), 3–27. https://doi.org/10.1177/1471082X1001200102

Altarriba, J., & Mathis, K. M. (1997). Conceptual and lexical development in second language acquisition. *Journal of Memory and Language*, *36*(4), 550–568. https://doi.org/10.1006/jmla.1997.2493

Amenta, S., & Crepaldi, D. (2012). Morphological processing as we know it: An analytical review of morphological effects in visual word identification. *Frontiers in Psychology*, *3*. https://doi.org/10.3389/fpsyg.2012.00232

Anderson, S. R. (1992). *A-morphous Morphology*. Cambridge, UK: Cambridge University Press.

Andersson, L. G., & Janson, T. (1997). *Languages in Botswana: Language ecology in Southern Africa*. Gaborone: Longman.

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*(3), 279–296. https://doi.org/10.1016/j.jml.2012.12.001

Aronoff, M. (1976). *Word formation in generative grammar.* Cambridge, MA: MIT Press.

Aronoff, M., Berg, K., & Heyer, V. (2016). Some implications of English spelling for morphological processing. *The Mental Lexicon, 11*(2), 164–185. https://doi.org/10.1075/ml.11.2.01aro

Arslan, S., Bastiaanse, R., & Felser, C. (2015). Looking at the evidence in visual world: Eye-movements reveal how bilingual and monolingual Turkish speakers process grammatical evidentiality. *Frontiers in Psychology*, *6*, 1387. https://doi.org/10.3389/fpsyg.2015.01387

Auclair-Ouellet, N., Fossard, M., Houde, M., Laforce, R., & Macoir, J. (2016a). Production of morphologically derived words in the semantic variant of primary progressive aphasia: Preserved decomposition and composition but impaired validation. *Neurocase*, *22*(2), 170–178. https://doi.org/10.1080/13554794.2015.1081391

Auclair-Ouellet, N., Fossard, M., Laforce, R., Bier, N., & Macoir, J. (2017). Conception or *conceivation? The processing of derivational morphology in semantic dementia. *Aphasiology*, *31*(2), 166–188. https://doi.org/10.1080/02687038.2016.1168918

Auclair-Ouellet, N., Macoir, J., Laforce, R., Bier, N., & Fossard, M. (2016b). Regularity and beyond: Impaired production and comprehension of inflectional morphology in semantic dementia. *Brain and Language*, *155-156*, 1–11. https://doi.org/10.1016/j.bandl.2016.02.002

Baayen, H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511801686

Baayen, H. (2014). Experimental and psycholinguistic approaches. In R. Lieber & P. Štekauer (Eds.), *The Oxford Handbook of Derivational Morphology* (pp. 95–117): Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199641642.013.0007

Baayen, H. (2014). Multivariate statistics. In R. Podesva & D. Sharma (Eds.), *Research Methods in Linguistics* (pp. 337–372). Cambridge, UK: Cambridge University Press. https://doi.org/10.4135/9781446214565.n11

Badecker, W., & Caramazza, A. (1987). The analysis of morphological errors in a case of acquired dyslexia. *Brain and Language*, *32*(2), 278–305. https://doi.org/10.1016/0093-934X(87)90129-5

Badecker, W., & Caramazza, A. (1991). Morphological composition in the lexical output system. Cognitive Neuropsychology, 8(5), 335-367. https://doi.org/10.1080/02643299108253377

Badecker, W., Hillis, A., & Caramazza, A. (1990). Lexical morphology and its role in the writing process: Evidence from a case of acquired dysgraphia. *Cognition*, *35*(3), 205–243. https://doi.org/10.1016/0010-0277(90)90023-D

Bagwasi, M. M. (2003). The functional distribution of Setswana and English in Botswana. *Language, Culture and Curriculum, 16*(2), 212–217. https://doi.org/10.1080/07908310308666669

Balota, D. A., Yap, M. J., Cortese, M. J., & Watson, J. M. (2008). Beyond mean response latency: Response time distributional analyses of semantic priming. *Journal of Memory and Language*, *59*(4), 495–523. https://doi.org/10.1016/j.jml.2007.10.004

Basnight-Brown, D. M., Chen, L., Hua, S., Kostić, A., & Feldman, L. B. (2007). Monolingual and bilingual recognition of regular and irregular English verbs: Sensitivity to form similarity varies with first language experience. *Journal of Memory and Language*, *57*(1), 65–80. https://doi.org/10.1016/j.jml.2007.03.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*, 1–48. https://doi.org/10.18637/jss.v067.i01

Beauvillain, C. (1996). The integration of morphological and whole-word form information during eye fixations on prefixed and suffixed words. *Journal of Memory and Language*, *35*(6), 801–820. https://doi.org/https://doi.org/10.1006/jmla.1996.0041

Bergman, M. W., Hudson, P. T. W., & Eling, P. A. T. M. (1988). How simple complex words can be: Morphological processing and word representations. *The Quarterly*

Journal of Experimental Psychology Section A, *40*(1), 41–72. https://doi.org/10.1080/14640748808402282

Beyersmann, E., Castles, A., & Coltheart, M. (2012). Morphological processing during visual word recognition in developing readers: Evidence from masked priming. *The Quarterly Journal of Experimental Psychology, 65*, 1306–1326. https://doi.org/10.1080/17470218.2012.656661

Beyersmann, E., Casalis, S., Ziegler, J. C., & Grainger, J. (2015a). Language proficiency and morpho-orthographic segmentation. *Psychonomic Bulletin & Review*, *22*(4), 1054–1061. https://doi.org/10.3758/s13423-014-0752-9

Beyersmann, E., Cavalli, E., Casalis, S., & Colé, P. (2016). Embedded stem priming effects in prefixed and suffixed pseudowords. *Scientific Studies of Reading*, *20*(3), 220–230. https://doi.org/10.1080/10888438.2016.1140769

Beyersmann, E., Kezilas, Y., Coltheart, M., Castles, A., Ziegler, J. C., Taft, M., & Grainger, J. (2018). Taking the book from the bookshelf: Masked constituent priming effects from compound words and nonwords. *Journal of Cognition*, *1*(1). https://doi.org/10.5334/joc.11

Beyersmann, E., Ziegler, J. C., & Grainger, J. (2015b). Differences in the processing of prefixes and suffixes revealed by a letter-search task. *Scientific Studies of Reading*, *19*(5), 360–373. https://doi.org/10.1080/10888438.2015.1057824

Bird, H., Howard, D., & Franklin, S. (2003). Verbs and nouns: The importance of being imageable. *Journal of Neurolinguistics, 16*(2–3), 113–149. https://doi.org/10.1016/S0911-6044(02)00016-7

Borovsky, A., Elman, J. L., & Fernald, A. (2012). Knowing a lot for one's age: Vocabulary skill and not age is associated with anticipatory incremental sentence interpretation in children and adults. *Journal of Experimental Child Psychology, 112,* 417–436. https://doi.org/10.1016/j.jecp.2012.01.005

Bosch, S., & Clahsen, H. (2016). Accessing morphosyntax in l1 and l2 word recognition: A priming study of inflected German adjectives. *The Mental Lexicon*, *11*(1), 26–54. https://doi.org/10.1075/ml.11.1.02bos

Bosch, S., Veríssimo, J., & Clahsen, H. (2019). Inflectional morphology in bilingual language processing: An age-of-acquisition study. *Language Acquisition*, *26*(3), 339–360. https://doi.org/10.1080/10489223.2019.1570204

Boudelaa, S., & Marslen-Wilson, W. D. (2005). Discontinuous morphology in time: Incremental masked priming in Arabic. *Language and Cognitive Processes*, *20*(1), 207–260. https://doi.org/10.1080/01690960444000106

Boudelaa, S., & Marslen-Wilson, W. D. (2011). Productivity and priming: Morphemic decomposition in Arabic. *Language and Cognitive Processes, 26*(4-6), 624–652. https://doi.org/10.1080/01690965.2010.521022

Brysbaert, M., Stevens, M., Mandera, P., & Keuleers, E. (2016). How many words do we know? Practical estimates of vocabulary size dependent on word definition, the degree of language input and the participant's age. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01116

Caplan, D. (1993). Toward a psycholinguistic approach to acquired neurogenic language disorders. *American Journal of Speech-Language Pathology*, *2*(1), 59–83. https://doi.org/10.1044/1058-0360.0201.59

Caplan, D., Kellar, L., & Locke, S. (1972). Inflection of neologisms in aphasia. *Brain: A Journal of Neurology*. https://doi.org/http://dx.doi.org/10.1093/brain/95.1.169

Caramazza, A., Miceli, G., Silveri, M. C., & Laudanna, A. (1985). Reading mechanisms and the organisation of the lexicon: Evidence from acquired dyslexia. *Cognitive Neuropsychology, 2*(1), 81–114. https://doi.org/10.1080/02643298508252862

Castles, A., Coltheart, M., Savage, G., Bates, A., & Reid, L. (1996). Morphological processing and visual word recognition evidence from acquired dyslexia. *Cognitive Neuropsychology*, *13*(7), 1041–1058. https://doi.org/10.1080/026432996381773

Chateau, D., Knudsen, E. V., & Jared, D. (2002). Masked priming of prefixes and the influence of spelling–meaning consistency. *Brain and Language*, *81*(1), 587–600. https://doi.org/10.1006/brln.2001.2549

Chung, Y., Rabe-Hesketh, S., Dorie, V., Gelman, A., & Liu, J. (2013). A Nondegenerate Penalized Likelihood Estimator for Variance Parameters in Multilevel Models. *Psychometrika, 78*(4), 685–709. https://doi.org/10.1007/s11336-013-9328-2

Ciaccio, L.A., Burchert, F., & Semenza, C. (2020). Derivational morphology in agrammatic aphasia: A comparison between prefixed and suffixed words. *Frontiers in Psychology, 11*: 1070. https://doi.org/10.3389/fpsyg.2020.01070

Ciaccio, L.A., Burchert, F., & Semenza, C. (under review). Morphological errors in acquired dyslexia: The case of prefixed words. Under review with *The Mental Lexicon.*

Ciaccio, L. A., & Clahsen, H. (2020). Variability and consistency in L1 and L2 morphological processing: A masked-priming study on prefixation and suffixation. *Language Learning, 70*(1), 103-136. https://doi.org/10.1111/lang.12370

Ciaccio, L. A., & Jacob, G. (2019). Native speakers like affixes, l2 speakers like letters? An overt visual priming study investigating the role of orthography in l2 morphological processing. *PLOS ONE*, *14*(12), e0226482. https://doi.org/10.1371/journal.pone.0226482

Ciaccio, L.A., Kgolo, N. & Clahsen, H. (2020). Morphological decomposition in Bantu: a masked priming study on Setswana prefixation. *Language, Cognition and Neuroscience, 35*(10), 1257-1271. https://doi.org/10.1080/23273798.2020.1722847

Clahsen, H. (2016). Contributions of linguistic typology to psycholinguistics. *Linguistic Typology, 20*, 599–614. https://doi.org/10.1515/lingty-2016-0031

Clahsen, H., & Felser, C. (2006). Grammatical processing in language learners. *Applied Psycholinguistics*, *27*(1), 3–42. https://doi.org/10.1017/S0142716406060024

Clahsen, H., & Ikemoto, Y. (2012). The mental representation of derived words: An experimental study of *–sa* and *–mi* nominals in Japanese. *The Mental Lexicon*, *7*(2), 147–182. https://doi.org/10.1075/ml.7.2.02cla

Clahsen, H., Sonnenstuhl, I., & Blevins, J. P. (2003). Derivational morphology in the German mental lexicon: A dual mechanism account. In H. Baayen & R. Schreuder (Eds.), *Morphological Structure in Language Processing* (125-155). Berlin: De Gruyter Mouton.

Clark, E. V. (2001). Morphology in language acquisition. In A. Spencer & A. M. Zwicky (Eds.), *The Handbook of Morphology* (pp. 374–389). Oxford: Blackwell. Retrieved from 10.1002/9781405166348.ch19

Cole, R. A. (1973). Listening for mispronunciations: A measure of what we hear during speech. *Perception & Psychophysics*, *13*(1), 153–156. https://doi.org/10.3758/BF03207252

Colé, P., Beauvillain, C., & Segui, J. (1989). On the representation and processing of prefixed and suffixed derived words: A differential frequency effect. *Journal of Memory and Language*, *28*(1), 1–13. https://doi.org/https://doi.org/10.1016/0749-596X(89)90025-9

Coltheart, M. (1980). Deep dyslexia: A review of the syndrome. In M. Coltheart, K. Patterson, & J. Marshall (Eds.), *Deep Dyslexia*. London: Routledge; Kegan Paul.

Coltheart, M. (2001). Assumptions and methods in cognitive neuropsychology. In *The Handbook of Cognitive Neuropsychology: What Deficits Reveal about the Human Mind.* (pp. 3–21). New York, NY, US: Psychology Press.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204. https://doi.org/10.1037//0033-295X.108.1.204

Creissels, D. (2006). Tswana verb morphology and the lexical integrity principle. *Lingue e Linguaggio, 1*, 49–66. https://doi.org/10.1418/22012

Crepaldi, D., Hemsworth, L., Davis, C. J., & Rastle, K. (2016). Masked suffix priming and morpheme positional constraints. *Quarterly Journal of Experimental Psychology*, *69*(1), 113–128. https://doi.org/10.1080/17470218.2015.1027713

Crepaldi, D., Rastle, K., Coltheart, M., & Nickels, L. (2010). 'Fell' primes 'fall', but does 'bell' prime 'ball'? Masked priming with irregularly-inflected primes. *Journal of Memory and Language, 63*(1), 83–99. https://doi.org/0.1016/j.jml.2010.03.002

Crepaldi, D., Rastle, K., Davis, C. J., & Lupker, S. J. (2013). Seeing stems everywhere: Position-independent identification of stem morphemes. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(2), 510–525. https://doi.org/10.1037/a0029713

Cutler, A., Hawkins, J. A., & Gilligan, G. (1985). The suffixing preference: A processing explanation. *Linguistics*, *23*(5), 723–758. https://doi.org/10.1515/ling.1985.23.5.723

Davis, C. J. (2000). Match Calculator [Computer software]. http://www.pc.rhul.ac.uk/staff/c.davis/utilities/matchcalc/index.htm

De Bleser, R., & Bayer, J. (1990). Morphological reading errors in a German case of deep dyslexia. In J.L. Nespoulous, P. Villiard (Eds.), *Morphology, Phonology, and Aphasia* (pp. 32–59). Springer Series in Neuropsychology. New York: Springer.

De Bleser, R., Cholewa, J., Stadie, N., & Tabatabaie, S. (2004). *Lemo – Lexikon modell-orientiert, Einzelfalldiagnostik bei Aphasie, Dyslexie und Dysgraphie*. München/Jena: Urban & Fischer.

Demuth, K. (2000). Bantu noun class systems: Loan word and acquisition evidence of semantic productivity. In G. Senft (Ed.), *Systems of Nominal Classifications* (pp. 270–292). Cambridge: Cambridge University Press.

de Velde, M. V., Bostoen, K., Nurse, D., & Philippson, G. (2018). *The Bantu languages* (2nd ed.). New York: Routledge.

Diependaele, K., Duñabeitia, J. A., Morris, J., & Keuleers, E. (2011). Fast morphological effects in first and second language word recognition. *Journal of Memory and Language*, *64*(4), 344–358. https://doi.org/10.1016/j.jml.2011.01.003

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition*, *37*(6), 895–908. https://doi.org/10.3758/MC.37.6.895

Domínguez, A., Alija, M., Rodriguez-Ferreiro, J., & Cuetos, F. (2010). The contribution of prefixes to morphological processing of Spanish words. *European Journal of Cognitive Psychology*, *22*(4), 569–595. https://doi.org/10.1080/09541440903007792

Domínguez, A., Cuetos, F., & Segui, J. (2000). Morphological processing in word recognition: A review with particular reference to Spanish data. *Psicológica*, *21*(2).

Domínguez, A., Segui, J., & Cuetos, F. (2002). The time-course of inflexional morphological priming. *Linguistics, 40*(2), 235– 260. https://doi.org/10.1515/ling.2002.011

Dryer, M. S. (2013). Prefixing vs. suffixing in inflectional morphology. In M. S. Dryer & M. Haspelmath (Eds.), *The World Atlas of Language Structures Online*. Leipzig: Max Planck Institute for Evolutionary Anthropology. Retrieved from https://wals.info/chapter/26

Duñabeitia, J. A., Laka, I., Perea, M., & Carreiras, M. (2009). Is *milkman* a superhero like *Batman*? Constituent morphological priming in compound words. *European*

Journal of Cognitive Psychology, *21*(4), 615–640. https://doi.org/10.1080/09541440802079835

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2008). Does darkness lead to happiness? Masked suffix priming effects. *Language and Cognitive Processes*, *23*(7), 1002–1020. https://doi.org/10.1080/01690960802164242

Druks, J., & Froud, K. (2002). The syntax of single words: Evidence from a patient with a selective function word reading deficit. Cognitive Neuropsychology, 19(3), 207–244. https://doi.org/10.1080/02643290143000141

Farhy, Y., Veríssimo, J., & Clahsen, H. (2017). Universal and par- ticular in morphological processing: Evidence from Hebrew. *The Quarterly Journal of Experimental Psychology, 71*(5), 1125–1133. https://doi.org/10.1080/17470218.2017.131091

Feldman, L. B. (1994). Beyond orthography and phonology: Differences between inflections and derivations. *Journal of Memory and Language*, *33*(4), 442–470. https://doi.org/10.1006/jmla.1994.1021

Feldman, L. B., Kostić, A., Basnight-Brown, D. M., Đurđević, D. F., & Pastizzo, M. J. (2010). Morphological facilitation for regular and irregular verb formations in native and non-native speakers: Little evidence for two distinct mechanisms. *Bilingualism: Language and Cognition*, *13*(2), 119. https://doi.org/10.1017/S1366728909990459

Ferrand, L. (2000). Reading aloud polysyllabic words and nonwords: The syllabic length effect reexamined. *Psychonomic Bulletin & Review*, *7*(1), 142–148. https://doi.org/10.3758/BF03210733

Ferrari Bridgers, F., & Kacinik, N. (2017). How linearity and structural complexity interact and affect the recognition of Italian derived words. *Journal of Psycholinguistic Research*, *46*(1), 175–200. https://doi.org/10.1007/s10936-016-9427-1

Fiorentino, R., & Fund-Reznicek, E. (2009). Masked morphological priming of compound constituents. *The Mental Lexicon*, *4*(2), 159–193. https://doi.org/10.1075/ml.4.2.01fio

Fiorentino, R., Naito-Billen, Y., & Minai, U. (2016). Morphological decomposition in Japanese de-adjectival nominals: Masked and overt priming evidence. *Journal of Psycholinguistic Research*, *45*(3), 575–597. https://doi.org/10.1007/s10936-015-9349-3

Fleischer, W., & Barz, I. (2007). *Wortbildung der deutschen Gegenwartssprache* (3rd ed.). Tübingen, Germany: Niemeyer.

Fodor, J. D. (1998). Learning To Parse? *Journal of Psycholinguistic Research*, *27*(2), 285–319. https://doi.org/10.1023/A:1023258301588

Foote, R. (2017). The storage and processing of morphologically complex words in L2 Spanish. *Studies in Second Language Acquisition, 39*, 735–767. https://doi.org/10.1017/S0272263115000376

Forster, K. I. (1998). The pros and cons of masked priming. *Journal of Psycholinguistic Research*, *27*(2), 203–233. https://doi.org/10.1023/A:1023202116609

Forster, K. I., & Azuma, T. (2000). Masked priming for prefixed words with bound stems: Does submit prime permit? *Language and Cognitive Processes*, *15*(4), 539–561. https://doi.org/10.1080/01690960050119698

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers, 35*, 116–124. https://doi.org/10.3758/BF03195503

Fudge, E. C. (1984). *English word-stress*. London: Allen & Unwin.

Funnell, E. (1987). Morphological errors in acquired dyslexia: A case of mistaken identity. *The Quarterly Journal of Experimental Psychology Section A*, *39*(3), 497–539. https://doi.org/10.1080/14640748708401801

Funnell, E. (2000). Deep dyslexia. In E. Funnell (Ed.), *Case Studies in the Neuropsychology of Reading* (pp. 27–55). London: Psychology Press.

Gelman, A., Jakulin, A., Pittau, M. G., & Su, Y.-S. (2008). A weakly informative default prior distribution for logistic and other regression models. *The Annals of Applied Statistics, 2*(4), 1360–1383. https://doi.org/10.1214/08-AOAS191

Giraudo, H., & Grainger, J. (2000). Effects of prime word frequency and cumulative root frequency in masked morphological priming. *Language and Cognitive Processes*, *15*(4), 421–444. https://doi.org/10.1080/01690960050119652

Giraudo, H., & Grainger, J. (2003). On the role of derivational affixes in recognizing complex words: Evidence from masked priming. In H. Baayen & R. Schreuder (Eds.), *Morphological structure in language processing* (pp. 209–232). Berlin: De Gruyter Mouton.

Givón, T. (1979). *On Understanding Grammar*. New York: Academic Press.

Göksel, A., & Kerslake, C. (2005). *Turkish: A Comprehensive Grammar*. London: Routledge.

González Alonso, J., Baquero Castellanos, S., & Müller, O. (2016). Masked constituent priming of English compounds in native and non-native speakers. *Language, Cognition and Neuroscience, 31*, 1038–1054. https://doi.org/10.1080/23273798.2016.1179770

Goodglass, H., & Menn, L. (1985). Is agrammatism a unitary phenomenon?. In M. Kean (Ed.), *Agrammatism* (pp. 1-26). London: Academic Press.

Grainger, J., & Beyersmann, E. (2017). Edge-aligned embedded word activation initiates morpho-orthographic segmentation. In B. H. Ross (Ed.), *Psychology of learning and motivation* (Vol. 67, pp. 285–317). Academic Press. https://doi.org/10.1016/bs.plm.2017.03.009

Grainger, J., Colé, P., & Segui, J. (1991). Masked morphological priming in visual word recognition. *Journal of Memory and Language*, *30*(3), 370–384. https://doi.org/http://dx.doi.org/10.1016/0749-596X(91)90042-I

Greenberg, J. H. (1957). *Essays in Linguistics*. Chicago & London: The University of Chicago Press.

Greenberg, J. H. (1963). Some universals of grammar with particular reference to the order of meaningful elements. In J. H. Greenberg (Ed.), *Universals of language* (pp. 73–113). London: MIT Press.

Günther, F., Smolka, E., & Marelli, M. (2019). 'Understanding' differs between English and German: Capturing systematic language differences of complex words. *Cortex, 116,* 168-175. https://doi.org/10.1016/j.cortex.2018.09.007

Gwilliams, L., & Marantz, A. (2018). Morphological representations are extrapolated from morpho-syntactic rules. *Neuropsychologia, 114*, 77–87. https://doi.org/10.1016/j.neuropsychologia.2018.04.015

Hall, C. J. (1988). Integrating diachronic and processing principles in explaining the suffixing preference. In J. A. Hawkins (Ed.), *Explaining Language Universals* (pp. 321–349). Oxford, UK: Blackwell.

Hall, C. J. (1992). *Morphology and Mind: A Unified Approach to Explanation in Linguistics*. London: Routledge.

Hamilton, A. C., & Coslett, H. B. (2007). Impairment in writing, but not reading, morphologically complex words. *Neuropsychologia*, *45*(7), 1586–1590. https://doi.org/10.1016/j.neuropsychologia.2006.12.003

Hamilton, A. C., & Coslett, H. B. (2008). Role of inflectional regularity and semantic transparency in reading morphologically complex words: Evidence from acquired dyslexia. *Neurocase*, *14*(4), 347–368. https://doi.org/10.1080/13554790802368679

Hasenäcker, J., Beyersmann, E., & Schroeder, S. (2015). Language proficiency moderates morphological priming in children and adults. In V. Pirrelli, C. Marzi, & M. Ferro (Eds.), *Proceedings of the NetWordS final conference on word knowledge and word usage: Representations and processes in the mental lexicon.* (pp. 132–135). Retrieved from http://ceur-ws.org/Vol-1347/

Hasenäcker, J., Beyersmann, E., & Schroeder, S. (2016). Masked morphological priming in German-speaking adults and children: Evidence from response time distributions. *Frontiers in Psychology, 7*, 929. https://doi.org/10.3389/fpsyg.2016.00929

Hasenäcker, J., Schröter, P., & Schroeder, S. (2017). Investigating developmental trajectories of morphemes as reading units in German. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(7), 1093–1108. https://doi.org/10.1037/xlm0000353

Hasenäcker, J., Solaja, O., & Crepaldi, D. (2020). Food in the corner and money in the cashews: Semantic activation of embedded stems in the presence or absence of a morphological structure. *Psychonomic Bulletin & Review*, *27*(1), 155–161. https://doi.org/10.3758/s13423-019-01664-z

Hawkins, J. A., & Cutler, A. (1988). Psycholinguistic factors in morphological asymmetry. In J. A. Hawkins (Ed.), *Explaining Language Universals* (pp. 280–317). Oxford, UK: Blackwell.

Hawkins, J. A., & Gilligan, G. (1988). Prefixing and suffixing universals in relation to basic word order. *Lingua*, *74*(2), 219–259. https://doi.org/10.1016/0024-3841(88)90060-5

Hay, J. (2001). Lexical frequency in morphology: Is everything relative? *Linguistics, 39*, 1041–1070. https://doi.org/10.1515/ling.2001.041

Heathcote, L., Nation, K., Castles, A., & Beyersmann, E. (2018). Do "blacheap" and "subcheap" both prime "cheap"? An investigation of morphemic status and position in early visual word processing. *Quarterly Journal of Experimental Psychology*, 17470218.2017.1. https://doi.org/10.1080/17470218.2017.1362704

Heide, J., Lorenz, A., Meinunger, A., & Burchert, F. (2010). The influence of morphological structure on the processing of German prefixed verbs. In A. Onysko, S. Michel (Eds.), *Cognitive Perspectives on Word Formation* (pp. 375-397). Berlin: De Gruyter Mouton.

Heister, J., Würzner, K.-M., Bubenzer, J., Pohl, E., Hanneforth, T., Geyken, A., & Kliegl, R. (2011). dlexDB – eine lexikalische Datenbank für die psychologische und linguistische Forschung. *Psychologische Rundschau*, *62*(1), 10–20. https://doi.org/10.1026/0033-3042/a000029

Heuven, W. J. B. van, Mandera, P., Keuleers, E., & Brysbaert, M. (2014). Subtlex-UK: A new and improved word frequency database for British English. *Quarterly Journal of Experimental Psychology*, *67*(6), 1176–1190. https://doi.org/10.1080/17470218.2013.850521

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 words. *Bilingualism: Language and Cognition*, *18*(3), 543–550. https://doi.org/10.1017/S1366728914000662

Heyer, V., & Kornishova, D. (2018). Semantic transparency affects morphological priming ... eventually. The Quarterly Journal of Experimental Psychology, 71(5), 1112–1124. https://doi.org/10.1080/17470218.2017.1310915

Hopp, H. (2014). Working memory effects in the L2 processing of ambiguous relative clauses. *Language Acquisition, 21*, 250–278. https://doi.org/10.1080/10489223.2014.892943

Hopp, H. (2015). Individual differences in the second language processing of object–subject ambiguities. *Applied Psycholinguistics, 36*, 129–173. https://doi.org/10.1017/S0142716413000180

Huber, W., Poeck, K., Weniger, D., & Willmes, K. (1983). *Der Aachener Aphasie Test* (AAT) [the Aachen aphasia test]. Göttingen: Hogrefe.

Hupp, J. M., Sloutsky, V. M., & Culicover, P. W. (2009). Evidence for a domain-general mechanism underlying the suffixation preference in language. *Language and Cognitive Processes*, *24*(6), 876–909. https://doi.org/10.1080/01690960902719267

Jacob, G., Fleischhauer, E., & Clahsen, H. (2013). Allomorphy and affixation in morphological processing: A cross-modal priming study with late bilinguals. *Bilingualism: Language and Cognition, 16*, 924–933. https://doi.org/10.1017/S1366728913000291

Jacob, G., Heyer, V., & Veríssimo, J. (2018). Aiming at the same target: A masked priming study directly comparing derivation and inflection in the second language. *International Journal of Bilingualism*, *22*(6), 619–637. https://doi.org/10.1177/1367006916688333

Jacob, G., & Kırkıcı, B. (2016). The processing of morphologically complex words in a specific speaker group: A masked-priming study with Turkish heritage speakers. *The Mental Lexicon*, *11*(2), 308–328. https://doi.org/10.1075/ml.11.2.06jac

Jakobson, R. (1941–1968). *Child Language, Aphasia, and Phonological Universals*. (H. Keiler, Trans.). The Hague: Mouton.

Jarema, G., Perlak, D., & Semenza, C. (2010). The processing of compounds in bilingual aphasia: A multiple–case study. *Aphasiology, 24*(2), 126-140. https://doi.org/10.1080/02687030902958225

Järvikivi, J., & Niemi, J. (1999). Linearity and morphological structure in derived words: Evidence from category decision. *Brain and Language*, *68*(1), 340–346. https://doi.org/10.1006/brln.1999.2089

Job, R., & Sartori, G. (1984). Morphological decomposition: Evidence from crossed phonological dyslexia. *The Quarterly Journal of Experimental Psychology Section A*, *36*(3), 435–458. https://doi.org/10.1080/14640748408402171

Kastovsky, D. (2005). Hans Marchand and the Marchandeans. In P. Štekauer & R. Lieber (Eds.), *Handbook of word-formation* (pp. 99-124). Dordrecht: Springer.

Kay, J. (1988). On the origin of morphological errors in two cases of acquired dyslexia. *Linguistics*, *26*(4), 669–698. https://doi.org/10.1515/ling.1988.26.4.669

Kazanina, N. (2011). Decomposition of prefixed words in Russian. Journal of *Experimental Psychology: Learning, Memory, and Cognition, 37*, 1371–1390. https://doi.org/10.1037/a0024335

Kazanina, N., Dukova-Zheleva, G., Geber, D., Kharlamov, V., & Tonciulescu, K. (2008). Decomposition into multiple morphemes during lexical access: A masked priming study of Russian nouns. *Language and Cognitive Processes*, *23*(6), 800–823. https://doi.org/10.1080/01690960701799635

Keijzer, M. (2010). The regression hypothesis as a framework for first language attrition. *Bilingualism: Language and Cognition*, *13*(1), 9–18. https://doi.org/10.1017/S1366728909990356

Kgolo, N. (2014). *The Mental Representation of Setswana Deverbative nouns: A Psycholinguistic Analysis of Class 1 and 9 Nominalisations* (Doctoral dissertation). University of Essex.

Kgolo, N., & Eisenbeiss, S. (2015). The role of morphological structure in the processing of complex forms: Evidence from Setswana deverbative nouns. *Language,* *Cognition and Neuroscience*, *30*(9), 1116–1133. https://doi.org/10.1080/23273798.2015.1053813

Kielar, A., Joanisse, M. F., & Hare, M. L. (2008). Priming English past tense verbs: Rules or statistics? *Journal of Memory and Language*, *58*(2), 327–346. https://doi.org/10.1016/j.jml.2007.10.002

Kilgarriff, A., Rychly, P., Smrz, P., & Tugwell, D. (2004). The sketch engine. In *Proceedings of Euralex* (pp. 105–116). Lorient, France.

Kim, S. Y., Wang, M., & Taft, M. (2015). Morphological decomposition in the recognition of prefixed and suffixed words: Evidence from Korean. *Scientific Studies of Reading*, *19*(3), 183–203. https://doi.org/10.1080/10888438.2014.991019

Kirkici, B., & Clahsen, H. (2013). Inflection and derivation in native and non-native language processing: Masked priming experiments on Turkish. *Bilingualism: Language and Cognition*, *16*(4), 776–791. https://doi.org/10.1017/S1366728912000648

Kuczaj, S. A., II. (1979). Evidence for a language learning strategy: On the relative ease of acquisition of prefixes and suffixes. *Child Development*, *50*(1), 1. https://doi.org/10.2307/1129034

Laganaro, M., Vacheresse, F., & Frauenfelder, U. H. (2002). Selective Impairment of Lexical Stress Assignment in an Italian-Speaking Aphasic Patient. *Brain and Language, 81*(1–3), 601–609. https://doi.org/10.1006/brln.2001.2550

Lago, S., Gračanin-Yuksek, M., Şafak, D. F., Demir, O., Kırkıcı, B., & Felser, C. (2019). Straight from the horse's mouth. Agreement attraction effects with Turkish possessors. *Linguistic Approaches to Bilingualism, 9*(3), 398–426. https://doi.org/10.1075/lab.17019.lag

Lázaro, M., Illera, V., & Sainz, J. (2016). The suffix priming effect: Further evidence for an early morpho-orthographic segmentation process independent of its semantic content. *Quarterly Journal of Experimental Psychology*, *69*(1), 197–208. https://doi.org/10.1080/17470218.2015.1031146

Lehtonen, M., Monahan, P. J., & Poeppel, D. (2011). Evidence for early morphological decomposition: Combining masked priming with magnetoencephalography. *Journal of Cognitive Neuroscience, 23*, 3366–3379. https://doi.org/10.1162/jocn_a_00035

Leminen, A., Smolka, E., Duñabeitia, J. A., & Pliatsikas, C. (2019). Morphological processing in the brain: The good (inflection), the bad (derivation) and the ugly (compounding). *Cortex, 116*, 4-44. https://doi.org/10.1016/j.cortex.2018.08.016

Letsholo, R., & Matlhaku, K. (2014). The syntax of the Setswana noun phrase. Marang: *Journal of Language and Literature, 24*, 22–42.

Li, J., & Taft, M. (2019). The processing of English prefixed words by Chinese-English bilinguals. *Studies in Second Language Acquisition*, 1–11. https://doi.org/10.1017/S0272263119000172

Li, J., Taft, M., & Xu, J. (2017a). The processing of English derived words by Chinese-English bilinguals. *Language Learning*, *67*(4), 858–884. https://doi.org/10.1111/lang.12247

Li, M., Jiang, N., & Gor, K. (2017b). L1 and L2 processing of compound words: Evidence from masked priming experiments in English. *Bilingualism: Language and Cognition*, *20*(2), 384–402. https://doi.org/10.1017/S1366728915000681

Libben, G. (1994). How is morphological decomposition achieved? *Language and Cognitive Processes*, *9*(3), 369–391. https://doi.org/10.1080/01690969408402124

Lieber, R. (1992). *Deconstructing morphology: Word formation in syntactic theory*. Chicago and London: University of Chicago Press.

Lima, S. D., & Pollatsek, A. (1983). Lexical access via an orthographic code? The basic orthographic syllabic structure (boss) reconsidered. *Journal of Verbal Learning and Verbal Behavior*, *22*(3), 310–332. https://doi.org/https://doi.org/10.1016/S0022-5371(83)90215-3

Longtin, C.-M., & Meunier, F. (2005). Morphological decomposition in early visual word processing. *Journal of Memory and Language*, *53*(1), 26–41. https://doi.org/10.1016/j.jml.2005.02.008

Lorenz, A. & Biedermann, B. (2015). Production of plural nouns in German: Evidence from non-fluent aphasia. *Language, Cognition and Neuroscience, (30)*7, 796-815. https://doi.org/10.1080/23273798.2015.1016442

Lorenz, A., Heide, J., & Burchert, F. (2014). Compound naming in aphasia: Effects of complexity, part of speech, and semantic transparency. *Language, Cognition and Neuroscience*, *29*(1), 88–106. https://doi.org/10.1080/01690965.2013.766357

Lorenz, A., & Zwitserlood, P. (2014). Processing of nominal compounds and gender-marked determiners in aphasia: Evidence from German. *Cognitive Neuropsychology, 31*(1), 40–74. https://doi.org/10.1080/02643294.2013.874335

Luzzatti, C. (2008). Acquired reading and writing disorders. In B. Stemmer & H. Whitaker (Eds.), *Handbook of the Neuroscience of Language* (pp. 209–218). San Diego: Academic Press.

Luzzatti, C., Mondini, S., & Semenza, C. (2001). Lexical representation and processing of morphologically complex words: Evidence from the reading performance of an Italian agrammatic patient. *Brain and Language*, *79*(3), 345–359. https://doi.org/10.1006/brln.2001.2475

Manelis, L., & Tharp, D. A. (1977). The processing of affixed words. *Memory & Cognition*, *5*(6), 690–695. https://doi.org/10.3758/BF03197417

Marantz, A. (2016). Morphology. In S. Small & G. Hickok (Eds.), *Neurobiology of Language* (pp. 153–163). https://doi.org/10.1016/b978-0-12-407794-2.00013-4

Marelli, M., Aggujaro, S., Molteni, F., & Luzzatti, C. (2012). The multiple-lemma representation of Italian compound nouns: A single case study of deep dyslexia. *Neuropsychologia*, *50*(5), 852–861. https://doi.org/10.1016/j.neuropsychologia.2012.01.021

Marelli, M., Aggujaro, S., Molteni, F., & Luzzatti, C. (2013). Understanding the mental lexicon through neglect dyslexia: A study on compound noun reading. *Neurocase*, *19*(2), 128–144. https://doi.org/10.1080/13554794.2011.654222

Marelli, M., Crepaldi, D., & Luzzatti, C. (2009). Head position and the mental representation of nominal compounds: A constituent priming study in Italian. *The Mental Lexicon*, *4*(3), 430–454. https://doi.org/10.1075/ml.4.3.05mar

Marslen-Wilson, W. D. (2007). Morphological processes in language comprehension. In M. G. Gaskell (Ed.), *The Oxford Handbook of Psycholinguistics* (Vol. 11, pp. 175–193). 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*(3), 394–421. https://doi.org/10.1080/01690960701588004

Marslen-Wilson, W. D., & Tyler, L. K. (1980). The temporal structure of spoken language understanding. *Cognition*, *8*(1), 1–71. https://doi.org/10.1016/0010-0277(80)90015-3

Marusch, T., Jäger, L. A., Burchert, F., & Nickels, L. (2017). Verb morphology in speakers with agrammatic aphasia. *The Mental Lexicon, 12*(3), 373–403. https://doi.org/10.1075/ml.17006.mar

Marusch, T., Malsburg, T. von der, Bastiaanse, R., & Burchert, F. (2012). Tense morphology in German agrammatism: The production of regular, irregular and mixed verbs. *The Mental Lexicon, 7*(3), 351–380. https://doi.org/10.1075/ml.7.3.05mar

Matthews, P. H. (1991). *Morphology* (2nd ed.). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9781139166485

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing Type I error and power in linear mixed models. *Journal of Memory and Language, 94,* 305–315. https://doi.org/10.1016/j.jml.2017.01.001

McCormick, S. F., Rastle, K., & Davis, M. H. (2008). Is there a “fete” in “fetish”? Effects of orthographic opacity on morpho-orthographic segmentation in visual word recognition. *Journal of Memory and Language*, *58*(2), 307–326. https://doi.org/10.1016/j.jml.2007.05.006

Meunier, F., & Marslen-Wilson, W. D. (2004). Regularity and irregularity in French verbal inflection. *Language and Cognitive Processes*, *19*(4), 561–580. https://doi.org/10.1080/01690960344000279

Meunier, F., & Segui, J. (2002). Cross-modal morphological priming in French. *Brain and Language*, *81*(1), 89–102. https://doi.org/10.1006/brln.2001.2509

Meunier, F., & Segui, J. (2003). Identification of spoken prefixed words in French. In R. H. Baayen & R. Schreuder (Eds.), *Morphological structure in language processing* (pp. 337–353). Berlin, New York: De Gruyter Mouton. https://doi.org/10.1515/9783110910186.337

Miceli, G., & Caramazza, A. (1988). Dissociation of inflectional and derivational morphology. *Brain and Language*, *35*(1), 24–65. https://doi.org/10.1016/0093-934X(88)90100-9

Miceli, G., Silveri, M.C., Romani, C., & Caramazza, A. (1989). Variation in the pattern of omissions and substitutions of grammatical morphemes in the spontaneous speech of so-called agrammatic patients. *Brain and Language, 36*(3), 447-492. https://doi.org/10.1016/0093-934X(89)90079-5

Miceli, G., Silveri, M. C., Villa, G., & Caramazza, A. (1984). On the basis for the agrammatic's difficulty in producing main verbs. *Cortex*, *20*(2), 207–220. https://doi.org/10.1016/S0010-9452(84)80038-6

Mithun, M. (1989). The acquisition of polysynthesis. *Journal of Child Language*, *16*(2), 285–312. https://doi.org/10.1017/S0305000900010424

Mondini, S., Arcara, G., & Semenza, C. (2012). Lexical and buffer effects in reading and in writing Noun-Noun compound nouns. *Behavioural Neurology, 25*(3), 245–253. http://dx.doi.org/10.3233/BEN-2012-119007

Montrul, S. (2009). Knowledge of tense-aspect and mood in spanish heritage speakers. *International Journal of Bilingualism*, *13*(2), 239–269. https://doi.org/10.1177/1367006909339816

Morris, J., & Stockall, L. (2012). Early, equivalent ERP masked priming effects for regular and irregular morphology. *Brain and Language*, *123*(2), 81–93. https://doi.org/10.1016/j.bandl.2012.07.001

Mousikou, P., & Schroeder, S. (2019). Morphological processing in single-word and sentence reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *45*(5), 881–903. https://doi.org/10.1037/xlm0000619

Nakano, Y., Ikemoto, Y., Jacob, G., & Clahsen, H. (2016). How orthography modulates morphological priming: Subliminal kanji activation in Japanese. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.00316

Neubauer, K., & Clahsen, H. (2009). Decomposition of inflected words in a second language: An experimental study of German participles. *Studies in Second Language Acquisition*, *31*(3), 403–435. https://doi.org/10.1017/S0272263109090354

Nikolova, R., & Jarema, G. (2002). Interaction of morphological structure and prefix transparency in the processing of Bulgarian aspectual verb forms. *Brain and Language*, *81*(1), 649–665. https://doi.org/10.1006/brln.2001.2554

Niswander-Klement, E., & Pollatsek, A. (2006). The effects of root frequency, word frequency, and length on the processing of prefixed English words during reading. *Memory & Cognition*, *34*(3), 685–702. https://doi.org/10.3758/BF03193588

Nooteboom, S. G. (1981). Lexical retrieval from fragments of spoken words: Beginnings vs. Endings. *Journal of Phonetics*, *9*(4), 407–424. https://doi.org/10.1016/S0095-4470(19)31017-4

Norcliffe, E., Harris, A. C., & Jaeger, T. F. (2015). Cross-linguistic psycholinguistics and its critical role in theory development: Early beginnings and recent advances. *Language, Cognition and Neuroscience, 30*(9), 1009–1032. https://doi.org/10.1080/23273798.2015.1080373

Osgood, C. E. (1949). The similarity paradox in human learning: A resolution. *Psychological Review*, *56*(3), 132–143. https://doi.org/10.1037/h0057488

Otlogetswe, T. J. (2012). *Tlhalosi ya medi ya Setswana.* Gaborone: Medi Publishing.

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*(1), 244–249. https://doi.org/10.1037//0278-7393.28.1.244

Patterson, K. (1980). Derivational errors. In M. Coltheart, K. Patterson, & J. Marshall (Eds.), *Deep dyslexia*. London: Routledge; Kegan Paul.

Patterson, K., & Ralph, M. A. L. (1999). Selective disorders of reading? *Current Opinion in Neurobiology, 9*(2), 235–239. https://doi.org/10.1016/S0959-4388(99)80033-6

Peirce, J. W. (2007). PsychoPy—Psychophysics software in python. Journal of *Neuroscience Methods, 162*(1), 8–13. https://doi.org/10.1016/j.jneumeth.2006.11.017

Penke, M., & Krause, M. (2002). German noun plurals: A challenge to the dual-mechanism model. *Brain and Language, 81*(1), 303–311. https://doi.org/10.1006/brln.2001.2526

Powell, M.. (2009). The BOBYQA Algorithm for Bound Constrained Optimization without Derivatives. Technical Report, Department of Applied Mathematics and Theoretical Physics.

Qu, Q., Cui, Z., & Damian, M. F. (2018). Orthographic effects in second-language spoken-word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *44*(8), 1325–1332. https://doi.org/10.1037/xlm0000520

Quémart, P., Casalis, S., & Colé, P. (2011). The role of form and meaning in the processing of written morphology: A priming study in French developing readers. *Journal of Experimental Child Psychology, 109*, 478–496. https://doi.org/10.1016/j.jecp.2011.02.008

R Development Core Team. (2014). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org

Ramscar, M. (2013). Suffixing, prefixing, and the functional order of regularities in meaningful strings. *Psihologija*, *46*(4), 377–396. https://doi.org/10.2298/PSI1304377R

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

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*(4), 507–537. https://doi.org/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*(6), 1090–1098. https://doi.org/10.3758/BF03196742

Rastle, K., Lavric, A., Elchlepp, H., & Crepaldi, D. (2015). Processing differences across regular and irregular inflections revealed through ERPs. *Journal of Experimental Psychology: Human Perception and Performance*, *41*(3), 747–760. https://doi.org/10.1037/a0039150

Rastle, K., Tyler, L. K., & Marslen-Wilson, W. D. (2006). New evidence for morphological errors in deep dyslexia. *Brain and Language*, *97*(2), 189–199. https://doi.org/10.1016/j.bandl.2005.10.003

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin, 114*, 510–532. https://doi.org/10.1037/0033-2909.114.3.510

Reifegerste, J., & Clahsen, H. (2017). Accessing morphosyntactic information is preserved at old age, except for irregulars. *The Mental Lexicon*, *12*(3), 342–372. https://doi.org/10.1075/ml.17008.rei

Reifegerste, J., Elin, K., & Clahsen, H. (2019). Persistent differences between native speakers and late bilinguals: Evidence from inflectional and derivational processing in older speakers. *Bilingualism: Language and Cognition*, *22*(3), 425–440. https://doi.org/10.1017/S1366728918000615

Reznick, J., & Friedmann, N. (2015). Evidence from neglect dyslexia for morphological decomposition at the early stages of orthographic-visual analysis. *Frontiers in Human Neuroscience*, *9*. https://doi.org/10.3389/fnhum.2015.00497

Saah, K., & Goodluck, H. (1995). Island effects in parsing and grammar: Evidence from Akan. *The Linguistic Review, 12*, 381–410. https://doi.org/10.1515/tlir.1995.12.4.381

Sapir, E. (1921). *Language: An Introduction to the Study of Speech*. New York: Harcourt, Brace; Company.

Sassenhagen, J., & Alday, P. M. (2016). A common misapplication of statistical inference: Nuisance control with null-hypothesis significance tests. *Brain and Language, 162*, 42–45. https://doi.org/10.1016/j.bandl.2016.08.001

Scalise S., Guevara E. (2005) The Lexicalist Approach to Word-Formation and the Notion of the Lexicon. In: Štekauer P., Lieber R. (Eds.), *Handbook of Word-Formation* (pp. 147- 187). Dordrecht: Springer. https://doi.org/10.1007/1-4020-3596-9_7

Schad, D. J., Hohenstein, S., Vasishth, S., & Kliegl, R. (2020). How to capitalize on a priori contrasts in linear (mixed) models: A tutorial. *Journal of Memory and Language, 110*, 104038. https://doi.org/10.1016/j.jml.2019.104038

Schriefers, H., Zwitserlood, P., & Roelofs, A. (1991). The identification of morphologically complex spoken words: Continuous processing or decomposition? *Journal of Memory and Language*, *30*(1), 26–47. https://doi.org/10.1016/0749-596X(91)90009-9

Selkirk, E. O. (1986). *The Syntax of Words* (3. print.). Cambridge, Mass.: The MIT Press.

Semenza, C., Arcara, G., Facchini, S., Meneghello, F., Ferraro, M., Passarini, L., … Mondini, S. (2011). Reading compounds in neglect dyslexia: The headedness effect. *Neuropsychologia*, *49*(11), 3116–3120. https://doi.org/10.1016/j.neuropsychologia.2011.07.020

Semenza, C., Butterworth, B., Panzeri, M., & Ferreri, T. (1990). Word formation: New evidence from aphasia. *Neuropsychologia*, *28*(5), 499–502. https://doi.org/https://doi.org/10.1016/0028-3932(90)90075-Y

Semenza, C., De Pellegrin, S., Battel, I., Garzon, M., Meneghello, F., & Chiarelli, V. (2011). Compounds in different aphasia categories: A study on picture naming. *Journal of Clinical and Experimental Neuropsychology*, *33*(10), 1099–1107. https://doi.org/10.1080/13803395.2011.603691

Semenza, C., Girelli, L., Spacal, M., Kobal, J., & Mesec, A. (2002). Derivation by prefixation in Slovenian: Two aphasia case studies. *Brain and Language*, *81*(1), 242–249. https://doi.org/10.1006/brln.2001.2521

Semenza, C., & Mondini, S. (2015). Word-formation in aphasia. In P. O. Müller, I. Ohnheiser, S. Olsen, & F. Rainer (Eds.), *Word-formation: An International Handbook of the Languages of Europe* (pp. 2154–2177). Berlin and Boston: De Gruyter Mouton. https://doi.org/10.1515/9783110375732-033

Shallice, T., & Warrington, E. K. (1975). Word Recognition in a Phonemic Dyslexic Patient. *Quarterly Journal of Experimental Psychology, 27*(2), 187–199. https://doi.org/10.1080/14640747508400479

Silva, R., & Clahsen, H. (2008). Morphologically complex words in l1 and l2 processing: Evidence from masked priming experiments in English. *Bilingualism: Language & Cognition*, *11*, 245–260. https://doi.org/https://doi.org/10.1017/S1366728908003404

Slobin, D. I. (1973). Cognitive prerequisites for the development of grammar. In A. Ferguson & D. I. Slobin (Eds.), *Studies of Child Language Development* (pp. 175–208). New York: Holt, Rinehart & Winston.

Smolìk, F. (2010). Inflectional suffix priming in czech verbs and nouns. In S. Ohlsson & R. Catrambone (Eds.), *Proceedings of the 32nd annual conference of the cognitive science society* (Vol. 32, pp. 1667–1672). Austin, TX: Cognitive Science Society.

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. https://doi.org/10.1016/j.jml.2013.12.002

Solomyak, O., & Marantz, A. (2010). Evidence for early morphological decomposition in visual word recognition. *Journal of Cognitive Neuroscience, 22*, 2042–2057. https://doi.org/10.1162/jocn.2009.21296

Sonnenstuhl, I., Eisenbeiss, S., & Clahsen, H. (1999). Morphological priming in the German mental lexicon. *Cognition*, *72*(3), 203–236. https://doi.org/10.1016/S0010-0277(99)00033-5

Spencer, A. (1988). Bracketing paradoxes and the English lexicon. *Language, 64*, 663–682. https://doi.org/10.2307/414563

Spencer, A. (1991). *Morphological Theory: An Introduction to Word Structure in Generative Grammar*. Oxford, UK: Blackwell.

Stanners, R. F., Neiser, J. J., Hernon, W. P., & Hall, R. (1979). Memory representation for morphologically related words. *Journal of Verbal Learning and Verbal Behavior*, *18*(4), 399–412. https://doi.org/10.1016/S0022-5371(79)90219-6

St. Clair, M. C., Monaghan, P., & Ramscar, M. (2009). Relationships between language structure and language learning: The suffixing preference and grammatical categorization. *Cognitive Science*, *33*(7), 1317–1329. https://doi.org/10.1111/j.1551-6709.2009.01065.x

Stockall, L., & Marantz, A. (2006). A single route, full decomposition model of morphological complexity: MEG evidence. *The Mental Lexicon*, *1*(1), 85–123. https://doi.org/10.1075/ml.1.1.07sto

Štekauer, P., Valera, S., & Kőrtvélyessy, L. (2012). *Word-Formation in the World's Languages: A Typological Survey*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511895005

Stump, G. T. (2001). *Inflectional Morphology: A Theory of Paradigm Structure.* Cambridge, UK: Cambridge University Press.

Sulpizio, S., Spinelli, G., & Burani, C. (2015). Stress affects articulatory planning in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance, 41*(2), 453–461. https://doi.org/10.1037/a0038714

Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory & Cognition*, *7*(4), 263–272. https://doi.org/10.3758/BF03197599

Taft, M. (1981). Prefix stripping revisited. *Journal of Verbal Learning and Verbal Behavior*, *20*(3), 289–297. https://doi.org/10.1016/S0022-5371(81)90439-4

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology Section A*, *57*(4), 745–765. https://doi.org/10.1080/02724980343000477

Taft, M., Li, S., & Beyersmann, E. (2018). What cross-morphemic letter transposition in derived nonwords tells us about lexical processing. *Journal of Cognition, 1*(1), 36. https://doi.org/10.5334/joc.39

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, *14*(6), 638–647. https://doi.org/10.1016/S0022-5371(75)80051-X

Talamas, A., Kroll, J. F., & Dufour, R. (1999). From form to meaning: Stages in the acquisition of second-language vocabulary. *Bilingualism: Language and Cognition*, *2*(1), 45–58. https://doi.org/10.1017/S1366728999000140

Taljard, E., & Bosch, S. E. (2006). A comparison of approaches to word class tagging: Disjunctively vs. conjunctively written Bantu languages. *Nordic Journal of African Studies, 15*(4), 428–442. http://uir.unisa.ac.za/handle/10500/21563

Tyler, L. K., Behrens, S., Cobb, H., & Marslen-Wilson, W. D. (1990). Processing distinctions between stems and affixes: Evidence from a non-fluent aphasic patient. *Cognition*, *36*(2), 129–153. https://doi.org/10.1016/0010-0277(90)90002-2

Tyler, L. K., & Cobb, H. (1987). Processing bound grammatical morphemes in context: The case of an aphasic patient. *Language and Cognitive Processes*, *2*(3), 245–262. https://doi.org/10.1080/01690968708406934

Tyler, L. K., Marslen-Wilson, W. D., Rentoul, J., & Hanney, P. (1988). Continuous and discontinuous access in spoken word-recognition: The role of derivational prefixes. *Journal of Memory and Language*, *27*(4), 368–381. https://doi.org/10.1016/0749-596X(88)90062-9

Ullman, M. T., Pancheva, R., Love, T., Yee, E., Swinney, D., & Hickok, G. (2005). Neural correlates of lexicon and grammar: Evidence from the production, reading, and judgment of inflection in aphasia. *Brain and Language*, *93*(2), 185–238. https://doi.org/10.1016/j.bandl.2004.10.001

Uygun, S., & Gu¨rel, A. (2017). Compound processing in second language acquisition of English. *Journal of the European Second Language Association, 1*, 90–101. https://doi.org/10.22599/jesla.21

Veivo, O., & Järvikivi, J. (2013). Proficiency modulates early orthographic and phonological processing in l2 spoken word recognition. *Bilingualism: Language and Cognition*, *16*(4), 864–883. https://doi.org/10.1017/S1366728912000600

Veivo, O., Järvikivi, J., Porretta, V., & Hyönä, J. (2016). Orthographic activation in l2 spoken word recognition depends on proficiency: Evidence from eye-tracking. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01120

Verhelst, N., Van Avermaet, P., Takala, S., Figueras, N., & North, B. (2009). *Common European framework of reference for languages: Learning, teaching, assessment*. Cambridge, UK: Cambridge University Press.

Veríssimo, J., Heyer, V., Jacob, G., & Clahsen, H. (2018). Selective effects of age of acquisition on morphological priming: Evidence for a sensitive period. *Language Acquisition*, *25*(3), 315–326. https://doi.org/10.1080/10489223.2017.1346104

Williams, E. (1981). On the notions "lexically related" and "head of a word". *Linguistic Inquiry*, *12*(2), 245–274. http://www.jstor.org/stable/4178218

Wurm, L. H. (1997). Auditory processing of prefixed English words is both continuous and decompositional. *Journal of Memory and Language*, *37*(3), 438–461. https://doi.org/10.1006/jmla.1997.2524