Journal of Experimental Psychology: Learning, Memory, and Cognition

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Online First Publication, July 9, 2018. http://dx.doi.org/10.1037/xlm0000619

American Psychological Association

Journal of Experimental Psychology: Learning, Memory, and Cognition

0278-7393/18/$12.00 http://dx.doi.org/10.1037/xlm0000619

Morphological Processing in Single-Word and Sentence Reading

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Research on morphological processing has been mainly conducted in the single-word reading domain using the lexical-decision task. Similar research in the sentence reading domain has been conducted using eye-tracking techniques, yet the experimental paradigms used in each domain are not directly comparable. In the present study, we investigated morphological processing in single-word reading using the masked priming paradigm (Experiments 1a, 1b, 3), and in sentence reading using the fast priming paradigm in eye tracking (Experiment 2). The study was conducted in German using the same prefixed and suffixed items in both tasks. All experiments yielded an identical pattern of results, indicating early processing of the embedded stems, independently of whether these stems were combined with a prefix, a suffix, or a nonmorphological letter sequence. We interpret our findings in relation to previous results in the literature and discuss their implications for reading research both in the single-word and sentence-reading domains.

Keywords: reading, morphology, masked priming, fast priming, eye tracking

How skilled readers recognize morphologically complex words (e.g., *player*, *playing*, *replay*) has been a topic of extensive research in psycholinguistics over the past 40 years. The reason why such words have attracted so much interest is because they comprise the vast majority of words in most of the world's languages, with morphologically rich languages, such as German for example, consisting mostly of words with two or more morphemes. Morphemes are the smallest meaningful units of a language and can be broadly classified into stems (e.g., *play*) and affixes (e.g., prefixes such as *re* in *replay* and suffixes such as *er* in *player* or *ing* in *playing*). Morphological decomposition, namely, decomposing morphologically complex words into their constituent morphemes, is thought to enable access to existing lexical representations, thus facilitating reading. Therefore, understanding the nature of morphological decomposition is critical for the development of theories of reading, and the implementation of computational models that can offer an explicit account of the mental processes underpinning our ability to read (for a review on this topic, see Amenta & Crepaldi, 2012).

Converging empirical evidence points to the idea that morphological decomposition is based on the words' visual form, a process known as morpho-orthographic decomposition (Rastle & Davis, 2008; Taft, 2004). Evidence for morpho-orthographic decomposition comes primarily from studies using the masked priming paradigm in a lexical-decision task (e.g., Longtin, Segui, & Hallé, 2003; Rastle, Davis, & New, 2004). In this paradigm, a series of hash marks is presented first in the center of the computer screen for around 500 ms followed by the prime stimulus, which is typically presented for 50 ms. The prime is then replaced by the target, which remains on the screen until participants respond (Forster & Davis, 1984). Participants tend to notice some flickering when the prime is replaced by the target, but they are unable to report the prime, even though its presence influences their responses to the target. In the above mentioned masked priming studies, for example, target words were recognized faster when they were preceded by briefly presented masked primes that were either morphologically and semantically related to the targets (e.g., *darkness*–DARK) or had an apparent morphological relationship with the targets (e.g., *corner*–CORN, where *corner* has nothing to do with *corn*, yet it consists of an apparent stem and a pseudosuffix), compared with when the primes were unrelated (e.g., *freedom*–DARK and *banker*–CORN, respectively). Importantly, target word recognition was not facilitated when primes and targets were orthographically but not morphologically related (e.g., *brothel*–BROTH, where *el* is not a suffix) compared to when they were unrelated (e.g., *warfare*–BROTH).

Morphological decomposition is also thought to occur before lexical identification, so that readers identify morphemes first, and then words (Taft, 1994). Evidence for this idea comes from masked priming studies that use morphologically structured nonwords as primes. Nonwords do not have a lexical representation; hence, decomposition of these items provides strong evidence for prelexical morphological processing. In a study carried out in French by Longtin and Meunier (2005), target word recognition was equally facilitated when the targets were preceded by morphologically structured nonwords (e.g., *rapidifier*–RAPIDE) and semantically transparent derived words (e.g., *rapidement*–

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This research was supported by a DFG grant awarded to Sascha Schroeder (SCHR-1268/2–1). The authors thank Katharina Pittrich for research assistance, and Marcus Taft, Davide Crepaldi for their constructive reviews.

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RAPIDE, where *rapidement* means "rapidly"). This was the case independently of whether the nonword primes consisted of syntactically legal (e.g., *rapidifier*–RAPIDE) or illegal (e.g., *sportation*–SPORT) combinations of stems and suffixes. Importantly, priming was not observed when primes and targets were orthographically, but not morphologically related (e.g., *rapiduit*–RAPIDE, where *uit* is not a suffix), further supporting the idea that morphological decomposition is orthographic in nature.

In a similar study, which was also conducted in French, Beyersmann, Ziegler, and Grainger (2015) compared priming effects for target words (e.g., TRISTE) that were preceded by suffixed word primes (e.g., *tristesse*, "sadness"), suffixed nonwords (e.g., *tristerie*), nonsuffixed nonwords (e.g., *tristald*, where *ald* is not a suffix), and unrelated word primes. They observed that participants with high levels of language proficiency showed equal priming in all related conditions (i.e., *tristesse/tristerie/tristald*–TRISTE) compared with an unrelated condition. In contrast, participants with lower language skills showed more priming in the suffixed conditions (i.e., *tristesse/tristerie*–TRISTE) compared to the nonsuffixed condition (i.e., *tristald*–TRISTE). Similar results have been obtained in other studies in both French and English (e.g., Beyersmann, Cavalli, Casalis, & Colé, 2016; Morris, Porter, Grainger, & Holcomb, 2010), thus suggesting that readers may simply benefit from the activation of embedded stems, independently of whether these stems are combined with an affix or a letter sequence that does not correspond to a morphological unit.

One serious limitation in this domain of research is that the debate about the nature of morphological decomposition has been based almost exclusively on results from studies that investigated single-word reading in word judgment tasks, which as Andrews, Miller, and Rayner (2004) point out, require task-specific decision processes that may themselves be sensitive to morphological complexity. Related to this is the idea that the mental processes supporting visual word recognition may be different in normal reading than in single-word reading (Rayner & Liversedge, 2011). Indeed, rarely do readers need to recognize words presented in isolation; word recognition typically occurs in the context of sentence or text reading (see also Amenta, Marelli, & Crepaldi, 2015, who highlight the importance of investigating how semantics may inform morphological decomposition during the early stages of reading using a task that reflects real-life reading situations such as sentence reading). As such, the findings from studies that investigate morphological processing in single-word reading do not necessarily extend to normal reading. Investigating the nature of such processes in sentence reading is thus warranted.

A number of studies have investigated morphological processing in sentence reading using eye tracking, yet most of these studies have focused on the processing of prefixed words (for a comprehensive review see Schotter, Angele, & Rayner, 2012), rather than on suffixed words, which have been the primary focus of studies in the single-word reading domain (see Table 1 in Rastle & Davis, 2008). Moreover, the few studies on morphological processing in sentence reading that can be compared to the abovementioned studies in the single-word reading domain have yielded an inconsistent pattern of results. For example, Lima (1987) and Kambe (2004) investigated morphological effects on parafoveal processing in English by comparing prefixed and nonprefixed words (e.g., *revive* vs. *rescue*) that were placed within identical sentence contexts. They found no evidence for facilitation in subsequent word-processing when the parafoveal preview corresponded to a morphological unit (i.e., the prefix *re* in *revive*) compared with a nonmorphological unit (i.e., the letter sequence *re* in *rescue*). In contrast, a series of studies conducted in Hebrew showed that the parafoveal preview of a word's morphological root, which is distributed throughout the word in Hebrew rather than being localized at the beginning or end of the word, facilitated target word reading (e.g., Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003; Deutsch, Frost, Pollatsek, & Rayner, 2000, 2005). These findings led to the idea that morphological preprocessing during normal reading may only occur in morphologically rich languages (see Schotter et al., 2012).

However, an earlier study conducted in Finnish, which is also a morphologically rich language, found no evidence for the idea that morphological information is parafoveally encoded (Hyönä, Vainio, & Laine, 2002). It is worth noting, however, that the results from two recent studies conducted in both Uighur and Finnish have revealed that the morphological structure of an upcoming word in a sentence can influence saccade programming during reading (Hyönä, Yan, & Vainio, 2018; Yan et al., 2014). Both Uighur and Finnish have an agglutinative syntax, so that inflectional affixes are systematically and incrementally added at the end of the word. In these studies, the initial landing position of the first fixation was closer to the beginning of the word in morphologically complex words than in monomorphemic words that were matched on length and frequency to the morphologically complex ones. This finding suggests that readers are able to extract information about the word's morphological structure from the parafovea and use it to guide saccadic targeting. However, whether this finding generalizes to nonagglutinative languages and morphological processes other than inflection (e.g., derivation) is unknown.

Another important difference between single-word and sentence-reading studies on morphological processing lies in the nature of the experimental paradigms used in each domain. In particular, most studies investigating morphological processing during sentence reading have employed the eye-contingent boundary paradigm (Rayner, 1975), which is used to assess the type and amount of information that readers extract from the parafovea. In the boundary paradigm, the critical conditions in which parafoveal information is manipulated change, whereas the control (baseline) condition does not change. Importantly, in the critical conditions, there is an invisible boundary that is placed to the left of the parafoveal letter string (known as preview), which can either be a word or a nonword. When the saccade crosses the invisible boundary the preview changes into the target word. The preview in the boundary paradigm has a similar function to the prime in the masked priming paradigm, in the sense that both the preview and the masked prime contain information that is available to the reading system before the target word is processed. Therefore, the boundary paradigm can be potentially used to investigate the preprocessing of morphological information in an ecologically valid way.

Nevertheless, a few fundamental differences between the boundary and masked priming paradigms make the results from sentence-reading and single-word reading studies that used these paradigms difficult to compare. For example, the amount of time spent on preprocessing the preview in the boundary paradigm (which is akin to the prime duration in masked priming) is not under experimental control, as it is the case in masked priming, but depends on the individual's reading skills. In addition, previews are processed parafoveally, whereas masked primes are processed foveally. This is an important difference, because parafoveal previews receive less attention, whereas masked primes are fully attended. Furthermore, while information from the preview is being extracted parafoveally, lexical, syntactic, and semantic processes are all at play during sentence reading. This is not the case in masked priming, where mainly lexical processing takes place while information from the prime is being extracted. It is therefore problematic to directly compare the results from single-word and sentence-reading studies that used the masked priming paradigm and the boundary paradigm, respectively.

One study that specifically sought to compare morphological processing in sentence reading and single-word reading using an eye-tracking paradigm that is comparable with masked priming was conducted by Paterson, Alcock, and Liversedge (2011). In their study, which used the stimuli from Rastle, Davis, and New (2004), prime-target word pairs with a semantically transparent morphological relationship (e.g., marshy-marsh), an opaque morphological relationship (e.g., secretary-secret), and an orthographic relationship (e.g., extract-extra) were embedded in sentences, so that the prime word appeared earlier in the sentence than the target word. Participants were instructed to read the sentences silently for comprehension, while eye movements were recorded. Target word reading was facilitated only when the preceding primes in the sentence were semantically and morphologically related to the targets (e.g., marshy–marsh). However, in contrast to the masked priming studies in the literature, the prime words in the sentence reading study of Paterson et al. (2011) were consciously identified prior to target word processing, potentially tapping different mechanisms in the reading process. As a consequence, earlier morphological and later semantic influences on target word processing could not be disentangled in that study.

The aim of the present study was to investigate the nature of morphological processing in single-word and sentence reading, using the same set of stimuli within comparable paradigms from the two domains. In particular, we conducted three experiments on single-word reading using the masked priming paradigm in a lexical-decision task, and one experiment on sentence reading using the fast priming paradigm in eye tracking (Sereno & Rayner, 1992). In this paradigm, a random letter string (mask) is presented first at the target word's location. When the reader moves his or her eyes across an invisible boundary which is located before the to-be-presented target word, the mask is replaced first by a briefly presented prime word or nonword, and then by the target word. Participants are instructed to read the sentence silently for comprehension. As in the masked priming paradigm, participants typically notice the change from the prime to the target, but are unaware of the identity of the prime. Importantly, the amount of time spent on preprocessing the prime in the fast priming paradigm can be experimentally manipulated in the same way as in masked priming. Also, primes in both paradigms are processed foveally, which means that in both cases they are fully attended, while similar linguistic processes are likely at play when information from the primes is being extracted. Such similarities between fast priming in eye tracking and masked priming in lexical decision make the two paradigms directly comparable. The fast priming paradigm has been used extensively to investigate the time course of orthographic and phonological processing in sentence reading (e.g., Lee, Rayner, & Pollatsek, 1999; Rayner, Sereno, Lesch, & Pollatsek, 1995) and has also been directly compared with the masked priming paradigm (Frisson, Bélanger, & Rayner, 2014). Yet, it has never been used to investigate morphological processing in sentence reading, thus making our study novel in this respect.

Another important feature of the present study is that both prefixed and suffixed items were used. Most eye-tracking studies on sentence reading have primarily used prefixed stimuli, whereas the vast majority of studies on single word reading have used suffixed stimuli. In addition, the few studies that used both prefixed and suffixed items in this research domain often obtained different results for each affix type, thus pointing to the idea that prefixed and suffixed words may be processed differently by the reading system (e.g., Beauvillain, 1996; Bergman, Hudson, & Eling, 1988; Beyersmann, Ziegler, & Grainger, 2015; Colé, Beauvillain, Pavard, & Segui, 1986; Colé, Beauvillain, & Segui, 1989; Feldman & Larabee, 2001; Giraudo & Grainger, 2003; Grainger, Colé, & Segui, 1991; Kim, Wang, & Taft, 2015; Meunier & Segui, 2002; but see Beyersmann et al., 2016, and Heathcote, Nation, Castles, & Beyersmann, 2017, who observed similar morphological priming effects for prefixed and suffixed items). This is likely, insofar as the stem of prefixed and suffixed items, which is important for accessing the meaning of the word, is located at word beginning in suffixed items, but at word ending in prefixed items. When a left-to-right parsing mechanism is at play (Kwantes & Mewhort, 1999) the word's meaning will be accessed earlier for suffixed items than for prefixed items. We hypothesized that such a left-to-right mechanism may be more pronounced in sentence reading than in single-word reading, because of the left-to-right nature of the former task. Thus, by directly comparing the processing of both prefixed and suffixed items in an eye-tracking study on sentence reading and a masked priming study on single single-word reading, we could test this idea.

The experiments were conducted in German, a morphologically rich language with a highly productive derivational system, which permitted the use of prefixed and suffixed items with overall similar characteristics. In Experiments 1a and 1b, which employed the masked priming paradigm, target words/stems (e.g., WAND, "wall" and BETT, "bed") were preceded by prefixed or suffixed forms of the target stems (e.g., *einwand,* "objection" and *bettlein*, "little bed"),[1] morphologically structured nonwords containing the target stem (e.g., *hinwand* and *bettlich*, where *hin* is a prefix and *lich* is a suffix), nonwords containing the target stem and a nonmorphological letter sequence (e.g., *karwand* and *bettpern,* where neither *kar* is a prefix nor *pern* is a suffix), unrelated morphologically complex words (e.g., *hingabe*, "dedication" and *peinlich*, "embarrassing"), and unrelated morphologically structured non-

[1] It is worth noting that the first letter of noun forms in German is written in capitals. However, in order to be consistent with all other studies that used the masked priming paradigm to investigate the same issue, and to keep the presentation of the primes consistent across conditions, all primes in the masked priming experiment, independently of their syntactic category, were presented in lowercase letters, while targets were presented in uppercase letters (see also Hasenäcker, Beyersmann, & Schroeder, 2016). In the eye-tracking experiment, targets that corresponded to nouns were presented in the sentence with their first letter written in capitals, while their preceding primes were presented in the same form.

words (e.g., *kargabe* and *peinpern*). The use of two control conditions, namely unrelated morphologically complex words and morphologically structured nonwords was motivated by the fact that previous studies in this research domain have typically used only word control primes. Word primes likely activate a lexical entry, which can potentially compete with the target word, thus inflating priming differences between the related and unrelated conditions. The use of nonword control primes (in addition to word control primes) allowed us thus to determine whether the use of a word control condition is problematic in this respect.

Experiment 1a used a blocked design, so that prefixed and suffixed items were presented in separate blocks. However, blocking by affix type may prime the location of the stem, thus facilitating access to it. For this reason, we carried out a second experiment (Experiment 1b), which was identical to Experiment 1a, except that prefixed and suffixed items were now presented intermixed. Experiments 1a and 1b were combined and analyzed together with type of design (blocked vs. mixed) entered as a factor in the analysis. In Experiment 2, which employed the fast priming paradigm in eye-tracking, the prefixed and suffixed word primes from Experiments 1a and 1b (e.g., *Einwand* and *Bettlein*) were embedded in sentences and used as targets, while the same primes as in the masked priming experiments were used. The masked priming experiments (Experiments 1a and 1b) used stems as targets, whereas the eye-tracking experiment (Experiment 2) used affixed forms as targets, because this is how the vast majority of masked priming and eye-tracking studies in the literature have typically examined morphological processing effects in reading (for a review of masked priming studies, see Rastle & Davis, 2008; for a review of eye-tracking studies, see Schotter et al., 2012). However, given that the main goal of the present study was to investigate the nature of morphological processing in reading by directly comparing results across paradigms and tasks, we carried out an additional masked priming experiment (Experiment 3), which used exactly the same prime-target pairs as the eye-tracking study (Experiment 2).

Experiment 1a

Method

Participants. Twenty-eight adult participants (19 females) from the Berlin area participated in the study for monetary compensation. Participants were native speakers of German, between 20- and 30-years-old, had normal or corrected-to-normal vision, and reported no hearing, reading, or language difficulties. Due to a technical error, three participants (one male and two females) were excluded from the study, thus yielding a total of 25 participants to be included in the analyses. Participants' reading performance, evaluated through the SLRT II reading test (Moll & Landerl, 2010) did not deviate from the population mean, neither for words ($M = 55.2$, $SD = 25.0$), $t(24) = 1.048$, $p = .305$, nor for nonwords ($M = 50.8$, $SD = 32.2$), $t(24) = 0.130$, $p = .897$. The study was approved by the ethics committee of the Max Planck Institute for Human Development and participants provided written consent prior to participating in the study.

Materials. Two types of affixed primes were used, prefixed and suffixed. The targets for both types of affixed primes consisted of 100 words and 100 nonwords that were three to nine letters long ($M = 5.4$, $SD = 1.1$) in the prefixed condition and three to seven letters long ($M = 4.7$, $SD = 1.0$) in the suffixed condition.[2] In the prefixed condition, target words consisted of nouns and verbs, whereas in the suffixed condition, the targets were nouns and adjectives. The targets' word frequency (prefixed: $M_{(\log 10)} = 1.7$, $SD = 0.8$; suffixed: $M_{(\log 10)} = 1.6$, $SD = 0.7$) and bigram frequency (prefixed: $M = 32.2$, $SD = 6.4$; suffixed: $M = 27.6$, $SD = 5.4$) were extracted from the DWDS corpus (Digitales Wörterbuch Deutscher Sprache, Version 0.4, January 2014; Geyken, 2007); and so was their Orthographic Levenshtein distance, which is known as OLD20 (Yarkoni, Balota, & Yap, 2008) and is given by the number of edits (insertions, deletions, and substitutions) required to transform one word into another (prefixed: $M = 1.1$, $SD = 0.2$; suffixed: $M = 1.2$, $SD = 0.3$). The OLD20 is based on the average edit distance of the 20 nearest neighbors in the lexicon. The higher the OLD20 value of a word or a nonword, the sparser its orthographic neighborhood. The target nonwords were generated by replacing one outer and one inner letter in an existing word.

For each target word (e.g., WAND or BETT) in each affix type condition, five primes were generated. Primes consisted of: (a) existing prefixed or suffixed forms of the target words (e.g., Einwand, Bettlein), which are equivalent of "subtitle" (for the target TITLE) and "farmer" (for the target FARM) in English, thus forming the *real morphological condition*; (b) nonwords comprising the target as a stem and a prefix (e.g., hinwand) or a suffix (e.g., bettlich), which are equivalent of "pretitle" (for the target TITLE) and "farmation" (for the target FARM) in English, thus forming the *pseudomorphological condition*; (c) nonwords comprising the target as a stem and a letter sequence that did not correspond to a prefix (e.g., karwand) or a suffix (e.g., bettpern), which are equivalent of "pratitle" (for the target TITLE) and "farmald" (for the target FARM) in English, thus forming the *nonmorphological condition*; (d) words comprising a stem that was unrelated to the target (i.e., Gabe, "gift" or Pein, "anguish") and a prefix (e.g., Hingabe, "dedication") or a suffix (e.g., peinlich, "embarrassing"), thus forming the *word control morphological condition*; and (e) nonwords comprising a stem that was unrelated to the target and a letter sequence that did not correspond to a prefix (e.g., kargabe) or a suffix (e.g., peinpern), thus forming the *nonword control condition*.

For each target nonword (e.g., LAFE or ZULT) in each affix type condition, five nonword primes were generated following the same logic (e.g., auslafe, mitlafe, kinlafe, mitfomt, kinfomt, in the prefixed condition, and zulthaft, zultheit, zultucht, zeutheit, zeutucht, in the suffixed condition), where "aus" and "mit" are prefixes and "haft" and "heit" are suffixes, whereas "kin" and "ucht" are letter sequences that do not correspond to a prefix or a suffix. The primes corresponding to the same target were matched on length in all five conditions. Ten prefixes (i.e., aus, ein, zu, un, um, vor, mit, hin, los, her) were used for the construction of the prefixed primes and 10 suffixes (i.e., haft, ig, los, isch, lich, chen, in, heit, lein, ung) were used for the construction of the suffixed

[2] Due to an oversight, four target words (i.e., Baum, Glück, Rat, Ruhe) were repeated in the prefixed and suffixed conditions and one prime nonword (i.e., emgang) was used twice in the prefixed condition.

primes.[3] Similarly, 10 letter sequences that did not correspond to a prefix were used as beginnings in the prefixed condition (i.e., gol, kin, og, lu, em, kar, tak, fos, hem, eps), and 10 different letter sequences that did not correspond to a suffix were used as endings in the suffixed condition (i.e., pern, au, men, nauf, ucht, pfen, am, tern, icht, ekt).

The primes within each affix type condition had exactly the same letter length (prefixed: $M = 8.0$, $SD = 1.3$, range = 5–12; suffixed: $M = 8.1$, $SD = 1.3$, range = 5–11) and were matched as closely as possible on important psycholinguistic variables such as OLD20 and bigram frequency, which are thought to influence visual word recognition and reading processes. However, due to their different lexical status, nonword primes (i.e., primes in the *pseudomorphological*, *nonmorphological*, and *nonword control* conditions) naturally had a higher OLD20, thus a sparser neighborhood, than word primes (i.e., primes in the *real* and *word control morphological* conditions). Similarly, nonword primes in the *nonword control* and *nonmorphological* conditions, which naturally contained less frequent letter sequences, had a slightly lower bigram frequency than the primes in the other three conditions (i.e., *real*, *pseudo*, and *word control morphological* conditions). Bigram frequency was calculated by log-transforming first the individual bigram frequencies for each prime, and then by summing them up. The psycholinguistic properties of the primes are shown in Table 1, while the word targets with their corresponding prefixed and suffixed primes are shown in Appendix A.

Procedure. One-hundred prime-target pairs for each type of target (words and nonwords) in five prime type conditions made a total of 200 trials per participant for each affix type condition. This meant that there were 20 trials per priming condition. Five lists were created with each target word appearing only once within a list, and once in each of the five prime type conditions across the five lists. Five participants were assigned to each list. The word and nonword targets were presented intermixed. The order of trial presentation within each list was randomized across participants. Half of the participants were tested first on the prefixed condition and the other half on the suffixed condition. All participants were tested on both affix type conditions, thus yielding a total of 400 trials per participant.

Participants were tested individually, seated approximately 60 cm in front of a laptop monitor in a quiet and dimly lit room. Stimulus presentation and data recordings were controlled by DMDX software (Forster & Forster, 2003). Participants were told that a series of hash marks would be displayed on the computer screen, followed by words/nonwords presented in uppercase letters, and that their task was to press “K” if the letter string was a word and “D” if the letter string was a nonword. Participants were instructed to respond as quickly and as accurately as possible. The presence of primes was not mentioned to them. Each trial started with the presentation of a forward mask (consisting of 12 hash marks) that remained on the screen for 500 ms. The prime was then presented in lowercase letters for 50 ms (three ticks based on the monitor’s refresh rate of 16.67 ms), followed by the target, which was presented in uppercase letters and acted as a backward mask to the prime. The stimuli appeared in white on a black background (14-point Courier New font) and remained on the screen for 3,000 ms or until participants responded, whichever happened first.

Experiment 1b

Method

Participants. Twenty-seven adult participants (18 females) from the Berlin area, none of whom had taken part in Experiment 1a, participated in the study for monetary compensation. Participants were native speakers of German, between 18- and 33-years-old, had normal or corrected-to-normal vision, and reported no hearing, reading, or language difficulties. One participant pressed the wrong button (“F” instead of “K”) during the first half of the experiment, thus producing a significant number of timeouts. This participant was not included in the analyses. Participants’ reading performance was evaluated through the SLRT II reading test. One participant produced a very low score compared to the rest and was removed, thus yielding a total of 25 participants to be included in the analyses.[4] Participants’ reading performance was above average for both words ($M = 70.0$, $SD = 16.4$), $t(24) = 6.079$, $p < .001$, and nonwords ($M = 69.5$, $SD = 24.3$), $t(24) = 4.024$, $p < .001$, thus deviating from the population mean. The study was approved by the ethics committee of the Max Planck Institute for Human Development and participants provided written consent prior to participating in the study.

Materials. The same materials as for Experiment 1a were used in Experiment 1b.

Procedure. Two-hundred prime-target pairs for each type of target (words and nonwords) in five prime type conditions made a total of 400 trials per participant for each affix type condition. The same five lists as in Experiment 1a were used with each target word appearing only once within a list, and once in each of the five prime type conditions across the five lists. Five participants were assigned to each list. The items in the prefixed and suffixed condition were intermixed, and so were the word and nonword targets. The order of trial presentation within each list was randomized across participants. The rest of the procedure was identical to that used in Experiment 1a.

Results

The analyses were performed using (generalized) linear mixed-effects models (Baayen, Davidson, & Bates, 2008) as implemented in the lme4 package (Version 1.1–13; Bates, Maechler, Bolker, & Walker, 2015) in the statistical software R (Version 3.3.3, R Core Team, 2017). Only reaction times (RTs) to words were analyzed. The BoxCox procedure was used to determine the best transformation to normalize residuals and RTs were then analyzed using a linear mixed-effects (LME) model. For the error analysis, a generalized linear mixed-effects model was created using logit transformation and a binomial link function.

Experiments 1a (blocked design) and 1b (mixed design) were analyzed together. The LME model included the effect-coded fixed effects of prime type (real morphological vs. pseudomorphological vs. nonmorphological vs. word control vs. nonword con-

[3] Due to the high productivity of German, an additional suffix (-nis) had to be used for the construction of some of the nonword primes in the pseudomorphological condition.

[4] It is worth noting that we also ran the analyses including the participant with the low SLRT score and the results were similar to the ones we report.

Table 1
Psycholinguistic Properties of the Primes in All Experiments

Prime types	Frequency (log10)		OLD20		Bigram frequency	
	M (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
Prefixed						
realmorph	−1.1 (1.3)	−2.1–1.8	1.9 (.3)	1.4–2.8	45.4 (7.8)	29.7–67.6
pseudomorph			2.0 (.3)	1.5–2.9	45.3 (7.8)	29.5–67.2
nonmorph			2.4 (.4)	1.7–3.9	44.3 (7.6)	29.6–66.5
wordcontrol	−.6 (1.3)	−2.1–2.2	1.9 (.3)	1.4–2.9	45.2 (7.5)	27.6–65.3
nonwordcontrol			2.5 (.4)	1.8–3.5	44.1 (7.3)	27.8–64.6
Suffixed						
realmorph	−.8 (1.4)	−2.1–2.1	2.0 (.3)	1.5–2.9	45.2 (6.6)	29.0–61.1
pseudomorph			2.4 (.5)	1.4–3.7	45.2 (6.8)	30.0–62.3
nonmorph			2.5 (.6)	1.6–4.0	44.8 (6.9)	28.2–60.8
wordcontrol	−1.0 (1.4)	−2.1–2.6	2.1 (.4)	1.3–3.2	44.9 (6.9)	30.9–62.6
nonwordcontrol			2.6 (.6)	1.7–3.9	44.5 (7.0)	29.5–61.4

trol), affix type (prefixed vs. suffixed), design type (blocked vs. mixed), and trial order (standardized), as well as their interaction. OLD20 and bigram frequency (both standardized) were also included in the model as covariates to control for differences between the different prime type conditions. Random intercepts and random slopes for prime type were used for both subjects and items. The model with the maximal random effects structure did not converge, hence uncorrelated random intercepts and slopes were used. The significance of the fixed effects was determined with type III model comparisons using the ANOVA function in the car package (Fox & Weisberg, 2011). If necessary, post hoc comparisons were carried out using cell means coding and single *df* contrasts with the glht function of the multcomp package (Hothorn, Bretz, & Westfall, 2008) using the normal distribution to evaluate significance.

Incorrect responses to words and nonwords were first removed (4.0% of the data). For the analysis of RTs, any latencies below 200 ms or above 2,000 ms (0.3% of the data) were considered as extreme values and were also removed. The BoxCox procedure indicated that inverse RT was the best transformation to normalize residuals. Outliers were subsequently removed following the procedure outlined by Baayen and Milin (2010). In particular, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (1.7% of the data).

Results indicated a significant main effect of prime type. The main effects of affix type and design type were not significant. Importantly, neither the interaction between prime type and affix type nor the interaction between prime type and design type were significant, indicating similar priming effects for prefixed and suffixed items, as well as for items presented in a blocked and mixed manner. To quantify evidence for the null interaction (see Rouder, Speckman, Sun, Morey, & Iverson, 2009), we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type × Design Type interaction. The model without the interaction term was preferred by a factor of about 2,242 (±3.3%), which according to Jeffreys (1961) provides "very strong evidence" for the hypothesis that the effect of prime type is not modulated by affix type or design type. Also, the interaction between trial order and prime type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. Last, the interaction between affix type and design type approached significance. This was because prefixed and suffixed items yielded identical RTs in the mixed design (Experiment 1b), whereas suffixed items were responded to slightly (3 ms) faster than prefixed items in the blocked design (Experiment 1a). The model mean RTs are shown in Table 2, while the results from the mixed-effects analysis are provided in Table 3.

Post hoc contrasts for the effect of prime type further revealed that RTs were significantly faster when the targets were preceded by primes in the real morphological condition compared to primes in the pseudomorphological ($z = -2.573$, $p = .010$), nonmorphological ($z = -3.788$, $p < .001$), word control morphological ($z = -7.165$, $p < .001$), and nonword control ($z = -6.868$, $p < .001$) conditions. RTs were also significantly faster when the targets were preceded by primes in the pseudomorphological condition compared to primes in the word control morphological ($z = -5.023$, $p < .001$) and nonword control ($z = -5.522$, $p < .001$) conditions. Similarly, RTs were significantly faster when the targets were preceded by primes in the nonmorphological condition compared to primes in the word control morphological ($z = -3.017$, $p = .003$) and nonword control ($z = -4.201$, $p < .001$) conditions. However, RTs to targets preceded by primes in the pseudomorphological and nonmorphological conditions did not differ significantly ($z = -1.692$, $p = .091$). This was also the

Table 2
Mean Model Reaction Times (Milliseconds) and Error Rates (%) to Word Targets by Prime Type and Affix Type in Combined Experiments 1a and 1b (SEs in Parentheses)

Prime type conditions	Prefixed		Suffixed	
	RTs	% Errors	RTs	% Errors
Real morphological	613 (11)	1.8 (.3)	603 (11)	1.7 (.3)
Pseudomorphological	618 (12)	2.3 (.4)	617 (11)	2.2 (.4)
Nonmorphological	625 (12)	2.5 (.4)	622 (12)	2.6 (.4)
Word control morphological	631 (12)	2.7 (.4)	638 (12)	2.9 (.5)
Nonword control	636 (12)	2.5 (.5)	639 (12)	2.3 (.5)

Table 3
Analysis of Variance Table for Word RT and Accuracy in Experiments 1a and 1b

Variables	RTs		Errors	
	χ^2	*p*	χ^2	*p*
Fixed effects (*df*)				
Intercept (1)	3434.662	<.001	639.284	<.001
Prime type (4)	83.932	<.001	15.047	=.005
Affix type (1)	.020	=.888	.004	=.951
Design (1)	.018	=.892	.000	=.993
Prime Type × Affix Type (4)	6.565	=.161	.690	=.953
Prime Type × Design (4)	5.925	=.205	1.967	=.742
Affix Type × Design (1)	3.683	=.055	2.589	=.108
Prime Type × Affix Type × Design (4)	1.724	=.786	.622	=.961
Trial order (1)	19.695	<.001		
Bigram frequency (1)	16.897	<.001	2.554	=.110
OLD20 (1)	1.465	=.226	.847	=.358

case for RTs to targets preceded by primes in the word control morphological and nonword control conditions ($z = -0.720$, $p = .472$).

We performed the error analysis in the same way as for RTs, except that trial order was not included in the model. Results showed a significant main effect of prime type. Post hoc contrasts for the effect of prime type further revealed that the real morphological condition yielded significantly fewer errors than the pseudomorphological ($z = 1.980$, $p = .048$), nonmorphological ($z = 2.922$, $p = .003$), and word control ($z = 3.659$, $p < .001$) conditions. No other conditions differed significantly. The model mean errors are shown in Table 2, while the results from the mixed-effects analysis on errors are provided in Table 3.

Discussion

We carried out two masked priming experiments, in which target word stems were preceded by: (a) prefixed or suffixed forms of the target stems (*real morphological condition*); (b) morphologically structured nonwords comprising the target stem and a prefix or a suffix (*pseudomorphological condition*); (c) nonmorphologically structured nonwords comprising the target stem and a nonmorphological letter sequence (*nonmorphological condition*); (d) unrelated prefixed or suffixed words (*word control morphological condition*); and (e) unrelated nonmorphologically-structured nonwords (*nonword control condition*). We found that response latencies to the targets were faster in the real morphological condition compared to all other conditions. Also, target words were recognized faster in the pseudomorphological and nonmorphological conditions compared with the word control morphological and nonword control conditions. Critically, the pseudomorphological and nonmorphological conditions did not differ significantly from each other, thus providing support for embedded stem activation that is independent of the presence of an affix (Beyersmann, Casalis, Ziegler, & Grainger, 2015; Beyersmann et al., 2016; Morris et al., 2010). Further, the word control morphological and nonword control conditions yielded similar RTs, thus rejecting the idea that the use of word primes in the control condition may inflate priming differences between the related and unrelated conditions as a result of competition between word primes and targets. In Experiment 1a, prefixed and suffixed items were presented in separate blocks, whereas in Experiment 1b they were intermixed. Our results convincingly showed that blocking by affix does not have an impact on the observed priming effects.

Experiment 2 involves a sentence reading task that employs the fast priming paradigm in eye tracking using the same stimuli as Experiments 1a and 1b and the same prime duration. This experiment seeks to determine whether the observed effects in single-word reading generalize to normal reading.

Experiment 2

Method

Participants. Twenty-six adult participants (20 females) from the Berlin area, none of whom had taken part in Experiments 1a and 1b, participated in the study for monetary compensation. Participants were native speakers of German, between 20- and 30-years-old, had normal or corrected-to-normal vision, and reported no hearing, reading, or language difficulties. Due to calibration problems and excessive blinking, one participant was discarded. Thus, a total of 25 participants were included in the analyses. Participants' reading performance, evaluated through the SLRT II reading test, was slightly above average for both words ($M = 63.4$, $SD = 26.2$), $t(24) = 2.564$, $p = .017$, and nonwords ($M = 67.2$, $SD = 26.9$), $t(24) = 3.193$, $p = .004$, thus deviating from the population mean. The study was approved by the ethics committee of the Max Planck Institute for Human Development and participants provided written consent prior to participating in the study.

Materials. The prefixed and suffixed primes that formed the *real morphological condition* in Experiments 1a and 1b served as targets in Experiment 2. Prefixed targets corresponded to nouns and verbs, while suffixed targets corresponded to nouns and adjectives. Target words were embedded in sentences, which were six to 10 words long ($M = 7.6$, $SD = 1.0$) in the prefixed condition and six to nine words long ($M = 7.6$, $SD = 1.0$) in the suffixed condition. The primes in Experiment 2 consisted of the same primes as in Experiments 1a and 1b, except that the *real morphological condition* now consisted of identity primes. Targets always appeared at the fifth position. Each sentence was displayed on a single line of text and the target words were preceded by words with an average length of 6.2 letters ($SD = 1.5$) in the prefixed condition and 6.5 letters ($SD = 1.9$) in the suffixed condition. The average log10 lemma frequency of the words in the fourth position that preceded the targets was 2.3 ($SD = 0.8$) in the prefixed condition and 2.1 ($SD = 0.9$) in the suffixed condition, according to the DWDS corpus.

Norms for target word predictability for each sentence were collected in an independent study with 70 20- to 30-year old native speakers of German. Word predictability refers to how predictable a certain word is when the preceding part of the sentence is known. Each participant performed a cloze task to a subgroup of the sentences, yielding a total of 14 observations per target word. The mean predictability of the target words was generally low (prefixed target words: $M = .02$, $SD = .07$ and suffixed target words: $M = .03$, $SD = .13$). Hence, the target words in our sentences were rarely predictable from the preceding context. The sentences are shown in Appendix B.

Apparatus. An EyeLink 1000 eyetracker (SR Research Ltd) was used to record eye-movements during reading at a rate of 1,000 Hz. Sentences were presented on a 21" ASUS LCD monitor, with a refresh rate of 120 Hz and a resolution of 1,024 × 768 pixels. Participants sat at a viewing distance of 60 cm with an assisting head and chin rest to reduce head movements. The words comprising the sentences were presented in black, in 14-point Courier New font (corresponding to 0.35° degrees of visual angle per letter) on a white background. The task was programmed in Experimental Builder (SR Research Ltd) using the fast priming paradigm (Sereno & Rayner, 1992). In particular, all target words contained a change from a random letter string (mask) to a word/nonword (prime) to the target word. The first change (i.e., from the mask to the prime) was triggered when the participants' eyes crossed an invisible boundary that was located at the end of the word preceding the target and before the space. Display changes took approximately 14 ms on average. When the boundary was crossed, the mask was replaced by the prime, which was presented for 50 ms. The prime was then replaced (via a second display change) by the target word, which remained on the screen until participants finished reading the sentence.

Procedure. One-hundred sentences for each affix type condition made a total of 200 sentences per participant. Five lists were created for each affix type condition, with each target word appearing only once within a list, and once in each of the five prime type conditions across the five lists. Five participants were assigned to each list. The order of sentence presentation within each list was randomized across participants. The sentences with the prefixed and suffixed targets were presented separately. Half of the participants read first the sentences with the prefixed targets while the other half read first the sentences with the suffixed items.

Testing took place at the eye tracking lab of the Max Planck Institute for Human Development in Berlin. A five-dot calibration of the eye tracker was conducted and validated with each participant until calibration accuracy below 0.4° was achieved. The eye tracker was recalibrated after four practice trials and after each block which comprised 10 sentences, or when x- or *y*-axis drift was detected. Participants were instructed to read each sentence silently and press a button on a gamepad with their right thumb once they had read the sentence. Twenty percent of the sentences were followed by a forced-choice comprehension question with the answers displayed at the bottom right and left corners of the screen. Participants were instructed to select the right answer by clicking the right or left buttons on the gamepad using their right and left index fingers. After five blocks (i.e., 50 sentences) a short break was administered.

Results

The data were primarily analyzed in terms of gaze duration, single fixation duration, and first fixation duration on the target word. Gaze duration represents the sum of all first-pass fixations on the target word. Single fixation duration represents the duration of the first first-pass fixation on the target word when the target is only fixated once. First fixation duration represents the duration of the first first-pass fixation on the target word. It is worth noting, however, that if the reader fixates a word only once, first fixation duration, which is then called single fixation duration, and gaze duration for that word are identical. Thus, these measures only differ in whether refixations are taken into account or not. It is now typically assumed that the underlying processes that these measures tap are highly related (e.g., Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Consequently, we hypothesized that similar priming effects would be obtained for these three measures, which are thought to tap into very early stages of the reading process.

Prior to analyzing our data, any trials in which the participant blinked while reading the sentence, or trials in which the display change was executed early or more than 10 ms after fixation onset of the postboundary words (see Slattery, Angele, & Rayner, 2011), were removed. Altogether, these exclusions accounted for 24% of the data. In addition, all trials in which the sentence was reread more than five times, received less than three or more than 16 fixations, or in which the target word was skipped during first-pass reading, were excluded. This procedure led to the removal of an additional 2% of the trials.

We performed the analyses of the three eye-movement measures in the same way as we performed the combined analysis of the RTs in Experiments 1a and 1b, except that design type (blocked vs. mixed) was no longer relevant. Models included the effect-coded fixed effects of prime type (real morphological vs. pseudomorphological vs. nonmorphological vs. word control vs. nonword control), affix type (prefixed vs. suffixed), and trial order, as well as their interaction. OLD20 and bigram frequency were standardized and included in the model as covariates. Similarly to the analyses of Experiments 1a and 1b, uncorrelated random intercepts and slopes for prime type were used for both subjects and items. The BoxCox procedure indicated that log RT was the best transformation to normalize residuals. Therefore, all eye-movement measures were first log-transformed and then analyzed using a linear mixed-effects model.

Gaze duration. For the analyses of gaze duration, any durations below 50 ms or above 1,000 ms (0.3% of the data) were considered as extreme values and were removed. Outliers were subsequently removed in the same way as for the RT analysis in Experiments 1a and 1b. In particular, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (2.7% of the data). Results indicated a significant main effect of prime type. Most importantly, however, the main effects of affix type and its interaction with prime type were not significant, indicating similar priming effects for both prefixed and suffixed items. To quantify evidence for the null interaction, we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type interaction. The model without the interaction term was preferred by a factor of about 623 (±3.5%), which provides "very strong evidence" for the hypothesis that the effect of prime type is not modulated by affix type. Also, the interaction between trial order and prime type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. The model mean gaze durations are shown in Table 4 and the results from the mixed-effects analysis are provided in Table 5.

Post hoc contrasts for the effect of prime type further revealed that gaze durations were significantly shorter when the targets

Table 4

Mean Model Gaze Duration, Single Fixation Duration, First and Second Fixation Duration (Milliseconds) to Word Targets by Prime Type and Affix Type in Experiment 2 (SEs in Parentheses)

Variables	Prefixed				Suffixed			
	GD	SFD	FFD	STFD	GD	SFD	FFD	STFD
Prime type conditions								
realmorph	335 (14)	285 (12)	220 (7)	168 (8)	325 (13)	278 (11)	212 (7)	165 (8)
pseudomorph	376 (16)	330 (14)	246 (8)	160 (7)	376 (16)	320 (13)	246 (8)	163 (7)
nonmorph	380 (16)	321 (13)	244 (8)	162 (7)	381 (16)	315 (13)	238 (8)	165 (7)
wordcontrol	412 (17)	347 (15)	272 (9)	162 (7)	411 (17)	356 (15)	264 (8)	164 (7)
nonwordcontrol	414 (17)	351 (15)	269 (9)	163 (7)	411 (17)	344 (15)	263 (8)	167 (7)

Note. GD = gaze duration; SFD = single fixation duration; FFD = first fixation duration; STFD = second of two fixation duration.

were preceded by primes in the real morphological condition compared to primes in the pseudomorphological ($z = -7.090$, $p <$ .001), nonmorphological ($z = -7.230$, $p < .001$), word control morphological ($z = -11.210$, $p < .001$), and nonword control ($z = -11.440$, $p < .001$) conditions. Gaze durations were also significantly shorter when the targets were preceded by primes in the pseudomorphological condition compared to primes in the word control morphological ($z = -6.428$, $p < .001$) and nonword control ($z = -7.379$, $p < .001$) conditions. Similarly, gaze durations were significantly shorter when the targets were preceded by primes in the nonmorphological condition compared to primes in the word control morphological ($z = -5.056$, $p < .001$) and nonword control ($z = -6.405$, $p < .001$) conditions. However, gaze durations to targets preceded by primes in the pseudomorphological and nonmorphological conditions did not differ significantly ($z = -0.882$, $p = .378$). This was also the case for gaze durations to targets preceded by primes in the word control morphological and nonword control conditions ($z = -0.147$, $p =$ .883).

In the following, we only analyze those trials in which the target word was fixated only once (41%) or twice (49%) during first-pass reading. Trials in which the target word was fixated three times (9%) or more (1%) were excluded from any further analyses. In addition, for those cases where the targets were fixated twice, we analyzed the duration of both first and second fixation. The analyses of second fixation durations were carried out to determine whether the observed effects occur during the early stages of the reading process, as we hypothesized. The lack of priming effects on second fixation duration would confirm our hypothesis.

Single fixation duration. For the analyses of single fixation duration, any durations below 50 ms or above 1,000 ms (0.1% of the data) were considered as extreme values and were removed. In order to remove outliers, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (2.8% of the data). Results indicated a significant main effect of prime type. Most importantly, however, the main effects of affix type and its interaction with prime type were not significant, indicating similar priming effects for both prefixed and suffixed items. To quantify evidence for the null interaction, we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type interaction. The model without the interaction term was preferred by a factor of about 129 (±5.2%), which provides "very strong evidence" for the hypothesis that the effect of prime type is not modulated by affix type. Also, the interaction between trial order and prime type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. The model mean single fixation durations are shown in Table 4 and the results from the mixed-effects analysis are provided in Table 5.

Post hoc contrasts for the effect of prime type further revealed that single fixation durations were significantly shorter when the targets were preceded by primes in the real morphological condi-

Table 5

Analysis of Variance Table for Gaze Duration, Single Fixation Duration, First and Second Fixation Duration in Experiment 2

Variables	GD		SFD		FFD		STFD	
	χ^2	p	χ^2	p	χ^2	p	χ^2	p
Fixed effects (*df*)								
Intercept (1)	24153.675	<.001	26471.093	<.001	45325.490	<.001	24506.987	<.001
Prime type (4)	190.838	<.001	81.632	<.001	139.135	<.001	1.312	=.859
Affix type (1)	.524	=.469	.897	=.344	2.690	=.101	.329	=.566
Prime Type * Affix Type (4)	2.969	=.563	2.584	=.630	.927	=.921	.741	=.946
Trial order (1)	33.034	<.001	.344	=.558	4.145	=.042	8.279	=.004
Bigram frequency (1)	19.335	<.001	.390	=.532	.330	=.566	1.727	=.189
OLD20 (1)	2.685	=.101	4.856	=.028	5.332	=.021	.030	=.863

Note. GD = gaze duration; SFD = single fixation duration; FFD = first fixation duration; STFD = second of two fixation duration.

tion compared to primes in the pseudomorphological ($z = -5.108$, $p < .001$), nonmorphological ($z = -4.139$, $p < .001$), word control morphological ($z = -7.854$, $p < .001$), and nonword control ($z = -6.975$, $p < .001$) conditions. Single fixation durations were also significantly shorter when the targets were preceded by primes in the pseudomorphological condition compared to primes in the word control morphological ($z = -4.006$, $p < .001$) and nonword control ($z = -3.267$, $p = .001$) conditions. Similarly, single fixation durations were significantly shorter when the targets were preceded by primes in the nonmorphological condition compared to primes in the word control morphological ($z = -4.610$, $p < .001$) and nonword control ($z = -4.345$, $p < .001$) conditions. However, single fixation durations to targets preceded by primes in the pseudomorphological and nonmorphological conditions did not differ significantly ($z = 1.033$, $p = .302$). This was also the case for single fixation durations to targets preceded by primes in the word and nonword control conditions ($z = 0.533$, $p = .594$).

First (of two) fixation duration. For the analyses of first fixation duration, there were no durations below 50 ms or above 1,000 ms. In order to remove outliers, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (2.2% of the data). Results indicated a significant main effect of prime type. Most importantly, however, the main effects of affix type and its interaction with prime type were not significant, indicating similar priming effects for both prefixed and suffixed items. To quantify evidence for the null interaction, we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type interaction. The model without the interaction term was preferred by a factor of about 562 (±3.3%), which provides "very strong evidence" for the hypothesis that the effect of Prime Type is not modulated by Affix Type. Also, the interaction between Trial Order and Prime Type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. The model mean first fixation durations are shown in Table 4 and the results from the mixed-effects analysis are provided in Table 5.

Post hoc contrasts for the effect of prime type further revealed that first fixation durations were significantly shorter when the targets were preceded by primes in the real morphological condition compared to primes in the pseudomorphological ($z = -5.904$, $p < .001$), nonmorphological ($z = -4.767$, $p < .001$), word control morphological ($z = -10.29$, $p < .001$), and nonword control ($z = -9.177$, $p < .001$) conditions. First fixation durations were also significantly shorter when the targets were preceded by primes in the pseudomorphological condition compared to primes in the word control morphological ($z = -4.601$, $p < .001$) and nonword control ($z = -4.164$, $p < .001$) conditions. Similarly, first fixation durations were significantly shorter when the targets were preceded by primes in the nonmorphological condition compared to primes in the word control morphological ($z = -5.219$, $p < .001$) and nonword control ($z = -5.432$, $p < .001$) conditions. However, first fixation durations to targets preceded by primes in the pseudomorphological and nonmorphological conditions did not differ significantly ($z = 0.935$, $p = .350$). This was also the case for first fixation durations to targets preceded by primes in the word and nonword control conditions ($z = 0.359$, $p = .720$).

Second (of two) fixation duration. To determine whether the observed effects occur early during the reading process we also analyzed the second fixation duration in those cases where the targets were fixated twice. Any durations below 50 ms or above 1,000 ms (1.4% of the data) were considered as extreme values and were removed. In order to remove outliers, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (1.8% of the data). Results showed no significant main effects of prime type or affix type, while the interaction between prime type and affix type was also not significant. To quantify evidence for the null interaction, we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type interaction. The model without the interaction term was preferred by a factor of about 486 (±2.5%), which provides "very strong evidence" for the hypothesis that the effect of prime type is not modulated by affix type. Also, the interaction between trial order and prime type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. The model mean second fixation durations are shown in Table 4 and the results from the mixed-effects analysis are provided in Table 5.

Discussion

Experiment 2 involved a sentence reading task using the fast priming paradigm in eye tracking. In this experiment, the same stimuli as in Experiments 1a and 1b were used forming the same conditions. However, the targets in Experiment 2 corresponded to the prefixed and suffixed words that were used as primes in the real morphological condition in Experiments 1a and 1b, while the primes in this condition were now identical to the targets. We analyzed several eye movement measures that are thought to reflect early processing, namely gaze duration, single fixation duration, and first fixation duration. For all these measures, durations were shorter in the real (identity) morphological condition compared to all other conditions, and in the pseudomorphological and nonmorphological conditions compared to the word control and nonword control conditions. Critically, the pseudomorphological and nonmorphological conditions were processed identically, thus providing additional support for the idea that embedded stems are activated early during the reading process independently of whether they are accompanied by an affix or not. In addition, the word control and nonword control conditions yielded similar durations. The absence of a main effect of prime type on second fixation duration indicates that the obtained effects on the three eye-movement measures of interest (namely, gaze duration, single fixation duration, and first fixation duration) occur during the very early stages of the reading process. Thus, our findings in Experiment 2 extend the effects reported in the single-word reading literature to normal reading.

The main goal of the present study was to investigate the nature of morphological processing in reading by directly comparing results across paradigms and tasks (masked priming in single word reading vs. fast priming in sentence reading). The use of stems as targets in Experiments 1a and 1b and affixed forms as targets in Experiment 2 was thus not optimal for such a comparison. For this reason, we carried out an additional masked priming experiment

(Experiment 3), which also used affixed forms as targets, hence, exactly the same prime-target pairs as those used in the eye-tracking study (Experiment 2). The combined analysis of Experiments 1a and 1b showed that the type of design (blocked vs. mixed) did not modulate the priming effects observed across the different conditions. As such, Experiment 3 was run using a blocked design to keep it as similar as possible to the eye-tracking study (Experiment 2).

Experiment 3

Method

Participants. Twenty-nine adult participants (22 females) from the Berlin area, none of whom had taken part in Experiments 1a, 1b, or 2, participated in the study for monetary compensation. Participants were native speakers of German, between 19- and 34-years-old, had normal or corrected-to-normal vision, and reported no hearing, reading, or language difficulties. Participants' reading performance was evaluated through the SLRT II reading test. Four participants produced a low score compared to the rest and were removed, thus yielding a total of 25 participants to be included in the analyses.[5] Participants' reading performance was above average for both words (M = 65.4, SD = 18.5), $t(24)$ = 4.165, $p < .001$, and nonwords (M = 65.4, SD = 24.9), $t(24)$ = 3.097, p = .005, thus deviating from the population mean. The study was approved by the ethics committee of the Max Planck Institute for Human Development and participants provided written consent prior to participating in the study.

Materials. The same primes as for Experiments 1a and 1b were used in Experiment 3. However, the targets in Experiment 3 corresponded to the primes used in the real morphological condition. Hence, similarly to Experiment 2, the real morphological condition in Experiment 3 consisted of identity primes.

Procedure. One-hundred prime-target pairs for each type of target (words and nonwords) in five prime type conditions made a total of 200 trials per participant for each affix type condition. Five lists were created with each target word appearing only once within a list, and once in each of the five prime type conditions across the five lists. Five participants were assigned to each list. The word and nonword targets were presented intermixed. The order of trial presentation within each list was randomized across participants. Half of the participants were tested first on the prefixed condition and the other half on the suffixed condition. All participants were tested on both affix type conditions, thus yielding a total of 400 trials per participant.

Results

The analyses were performed in the same way as for the other experiments. The LME model included the effect-coded fixed effects of Prime Type (real morphological vs. pseudomorphological vs. nonmorphological vs. word control vs. nonword control), affix type (prefixed vs. suffixed), and trial order, as well as their interaction. OLD20 and bigram frequency were standardized and included in the model as covariates. Similarly to the analyses of Experiments 1a, 1b, and 2, uncorrelated random intercepts and slopes for prime type were used for both subjects and items.

Incorrect responses to words and nonwords were first removed (4.3% of the data). For the analysis of RTs, any latencies below 200 ms or above 2,000 ms (0.6% of the data) were considered as extreme values and were also removed. The BoxCox procedure indicated that inverse RT was the best transformation to normalize residuals. Outliers were subsequently removed following the procedure outlined by Baayen and Milin (2010). In particular, a base model, which included only participants and items as random intercepts, was fitted to the data and data points with residuals exceeding 2.5 *SD*s were removed (1.7% of the data).

Results indicated significant main effects of prime type and affix type. Importantly, the interaction between prime type and affix type was not significant, indicating similar priming effects for prefixed and suffixed items. To quantify evidence for the null interaction (see Rouder et al., 2009), we calculated the Bayes factor to compare the model we report against the model that did not include the Prime Type × Affix Type interaction. The model without the interaction term was preferred by a factor of about 2,069 (±5.0%), which according to Jeffreys (1961) provides "very strong evidence" for the hypothesis that the effect of prime type is not modulated by affix type. Also, the interaction between trial order and prime type was not significant, indicating similar priming effects throughout the experimental session. Trial order was then only modeled as a main effect. The model mean RTs are shown in Table 6 and the results from the mixed-effects analysis are provided in Table 7.

Post hoc contrasts for the effect of prime type further revealed that RTs were significantly faster when the targets were preceded by primes in the real morphological condition compared to primes in the pseudomorphological ($z = -4.287$, $p < .001$), nonmorphological ($z = -3.602$, $p < .001$), word control morphological ($z = -7.348$, $p < .001$), and nonword control ($z = -7.278$, $p < .001$) conditions. RTs were also significantly faster when the targets were preceded by primes in the pseudomorphological condition compared to primes in the word control morphological ($z = -3.049$, $p = .002$) and nonword control ($z = -3.877$, $p < .001$) conditions. Similarly, RTs were significantly faster when the targets were preceded by primes in the nonmorphological condition compared to primes in the word control morphological ($z = -3.503$, $p < .001$) and nonword control ($z = -4.974$, $p < .001$) conditions. However, RTs to targets preceded by primes in the pseudomorphological and nonmorphological conditions did not differ significantly ($z = 0.579$, $p = .563$). This was also the case for RTs to targets preceded by primes in the word control morphological and nonword control conditions ($z = -0.953$, $p = .341$). Post hoc contrasts for the effect of affix type showed that RTs were significantly faster for the suffixed than for the prefixed items ($z = -2.347$, $p = .019$).

We performed the error analysis in the same way as for RTs, except that trial order was not included in the model. Results showed a significant main effect of prime type. Post hoc contrasts for the effect of prime type further revealed that the real morphological condition yielded significantly fewer errors than the pseudomorphological ($z = 2.344$, $p = .019$), nonmorphological ($z = 2.304$, $p = .021$), word control morphological ($z = 2.428$, $p =$

[5] It is worth noting that we also ran the analyses including all of the participants and the results were similar to the ones we report.

Table 6
Mean Model Reaction Times (Milliseconds) and Error Rates (%) to Word Targets by Prime Type and Affix Type in Experiment 3 (SEs in Parentheses)

	Prefixed		Suffixed	
Prime type conditions	RTs	% Errors	RTs	% Errors
Real morphological	671 (24)	.9 (.3)	643 (22)	.9 (.3)
Pseudomorphological	695 (26)	1.6 (.4)	678 (24)	1.4 (.3)
Nonmorphological	696 (26)	2.0 (.5)	670 (24)	1.1 (.3)
Word control morphological	717 (27)	1.9 (.4)	696 (26)	1.1 (.3)
Nonword control	724 (28)	3.5 (.8)	702 (26)	2.2 (.5)

.015), and nonword control ($z = 5.507$, $p < .001$) conditions. Also, both the pseudomorphological and nonmorphological conditions yielded significantly fewer errors than the nonword control condition ($z = 3.096$, $p = .002$ and $z = 3.556$, $p < .001$, respectively). Last, the word control condition yielded significantly fewer errors than the nonword control condition ($z = 3.551$, $p < .001$). The model mean errors are shown in Table 6 and the results from the mixed-effects analysis are provided in Table 7.

Discussion

Experiment 3 used the same prime-target pairs as Experiment 2 in a masked priming task. The same results as in the other experiments were obtained, thus corroborating the view that skilled readers may readily activate embedded stems, independently of whether these stems are combined with an affix or a nonmorphological unit. Prefixed and suffixed items yielded similar results with regards to the different prime type conditions; however, in Experiment 3, suffixed items were also responded to faster than prefixed items. This was because in this experiment, the prefixed and suffixed primes that formed the real morphological condition in Experiments 1a and 1b were used as targets. As can be seen from Table 1, these items differed in terms of their frequency, so that suffixed items were higher in frequency than prefixed items, and so it is not surprising that responses to the former were faster than those to the latter.

General Discussion

Morphologically complex words form the vast majority of words in most of the world's languages, hence investigating how they are processed has been a central topic of research in the area of psycholinguistics. The most well supported view on the basis of the available empirical evidence posits that during the early stages of visual word recognition, there is a morpho-orthographic parsing mechanism that decomposes words with a real or an apparent morphological structure into their constituent morphemes (Rastle & Davis, 2008; Rastle et al., 2004). However, the results from a number of recent studies show that such a morpho-orthographic mechanism may not always be involved in visual word recognition (e.g., Beyersmann et al., 2015, 2016; Morris et al., 2010). The debate on the nature of morphological decomposition during reading has been mainly based on empirical evidence from studies in the single-word reading domain using the masked priming paradigm. However, word recognition typically occurs in the context of sentence reading, and so the mental processes supporting the recognition of morphologically complex words may be different in normal reading than in single-word reading.

The few studies that investigated morphological processing in sentence reading using eye-tracking techniques have yielded an inconsistent pattern of results. Furthermore, the results from such studies cannot be directly compared with the results obtained from masked priming studies, because the paradigms that are typically employed in each domain have important differences, while the nature of the experimental stimuli used in each case are usually different. In the present study, we aimed to bridge this gap between the two disciplines by investigating morphological processing both in single word and sentence reading using comparable paradigms and an identical set of experimental stimuli.

In three lexical decision tasks that used the masked priming paradigm (Experiments 1a, 1b, and 3), we found that: (a) target word recognition was facilitated when primes and targets were morphologically and semantically related (real morphological condition) compared with when they had an apparent morphological relationship (pseudomorphological condition), a purely orthographic relationship (nonmorphological condition), or were unrelated to each other (word and nonword control conditions); (b) target word recognition was facilitated in the pseudomorphological and nonmorphological conditions compared to the unrelated word and nonword control conditions, yet the pseudomorphological and nonmorphological conditions yielded similar RTs; and (c) the word and nonword control conditions yielded similar RTs.

The first result can be explained within the theoretical framework of Taft, Xu, and Li (2017), according to which, the activation of real word primes (e.g., farmer) may inhibit or strengthen the activation of their embedded stem (i.e., farm), which corresponds to the target. Neither pseudomorphological primes (i.e., farmation) nor nonmorphological primes (i.e., farmald) exist to either inhibit or strengthen the activation of the stem *farm*, and so priming effects would be expected to be stronger for *farmer*–FARM (real morphological condition) than for *farmation*–FARM (pseudomorphological condition) or *farmald*-FARM (nonmorphological condition), as well as the word and nonword control conditions in which primes and targets are completely unrelated.

The second result suggests that skilled readers activate embedded stems during word recognition, independently of whether these stems are combined with an affix or a nonmorphological unit (e.g., Beyersmann et al., 2015, 2016; Morris et al., 2010). This result can be

Table 7
Analysis of Variance Table for Word RT and Accuracy in Experiment 3

	RTs		Errors	
Variables	χ^2	p	χ^2	p
Fixed effects (*df*)				
Intercept (1)	896.374	<.001	466.201	<.001
Prime type (4)	81.352	<.001	29.998	<.001
Affix type (1)	5.508	=.019	2.994	=.084
Prime Type × Affix Type (4)	1.678	=.795	2.851	=.583
Trial order (1)	15.383	<.001		
Bigram frequency (1)	25.951	<.001	5.066	=.024
OLD20 (1)	1.242	=.265	5.721	=.017

explained by a recently developed account of edge-aligned embedded word processing (Grainger & Beyersmann, 2017), according to which, the very early stages of visual word recognition involve a morphology-blind process, which activates words embedded at the edges of a letter string (i.e., either at initial or final position). But how can our result be reconciled with other results in the literature, which provide evidence for a mechanism of morpho-orthographic decomposition (Rastle & Davis, 2008; Rastle et al., 2004)? Such a mechanism may only become relevant when the primes consist of morphologically structured *words* (i.e., *corner* type of items) rather than *nonwords* (as it was the case in our study). In particular, the activation of a prime word like *corner* may inhibit the activation of the target stem *corn*. Yet, such inhibition is likely compensated by morpho-orthographic decomposition processes (i.e., *corn* + *er*), thus facilitating target word recognition. Similarly, the activation of a prime word like *brothel* may inhibit the activation of the target stem *broth*, but morpho-orthographic decomposition does not occur in this case, because the embedded stem is combined with a nonaffix (i.e., *broth* + *el*). As a result, the *corner*–CORN type of items yield priming, whereas the *brothel*–BROTH type of items do not, a finding that supports the existence of a morpho-orthographic parsing mechanism during visual word recognition.

The third result shows that word and nonword control primes behave similarly. This is an important finding, insofar as word control primes are typically thought to activate their corresponding lexical entries, which can potentially compete with the target word, thus inflating priming differences between the related and unrelated conditions. The results from the present study establish, however, that the use of word primes in the control condition is not problematic in this respect.

Our findings on morphological processing in single-word reading were obtained when prefixed and suffixed items were presented in separate blocks (Experiment 1a), when they were intermixed (Experiment 1b), and when the targets consisted of affixed forms rather than stems (Experiment 3). Importantly, we also showed that the same results are obtained during sentence reading (Experiment 2). In the latter experiment, we employed an eye-tracking paradigm that is directly comparable to the masked priming paradigm, that is, the fast priming paradigm. The same prime duration (i.e., 50 ms) and experimental stimuli were used as in the masked priming experiments. We analyzed several eye-movement measures, which are all thought to tap into the very early stages of the reading process, namely, gaze duration, single fixation duration, and first fixation duration. To further determine whether the observed effects occur early during the reading process we also analyzed the second fixation duration in those cases where the targets were fixated twice. Critically, we obtained the same pattern of results as for response latencies for all early measures, and observed that the differences among the experimental conditions became apparent during the first fixation on the target word. This is an important finding, because it shows that the observed effects occur early and are not dependent on task-specific decision processes (Andrews et al., 2004). Thus, the results from Experiment 2 support the view that embedded stems are activated during normal reading.

It is worth noting that single word and sentence reading have been traditionally treated as separate disciplines. The present work shows that the factors that underpin processing in single-word reading may also operate in sentence reading, thus motivating more cross talk between the two disciplines. Also, a common criticism in this domain of research is that readers rarely need to recognize words in isolation, and so studies on single word reading lack ecological validity (Rayner & Liversedge, 2011). On the basis of the present results, the effects observed in single-word reading studies do not seem to be driven by task-specific processes which are completely unrelated to sentence reading (see also Ktori, Mousikou, & Rastle, 2018, who obtained similar results in single-word and sentence reading aloud in a study that sought to uncover the cues to stress assignment).

Another important aim of the present study was to determine whether prefixed and suffixed items are processed differently by the reading system. The vast majority of masked priming studies in this research domain have used suffixed items, whereas most eye-tracking studies that investigated morphological processing in sentence reading have used prefixed items. Importantly, studies that used both types of items have often obtained different results for each affix type. We reasoned that a potential explanation for the different results may have to do with the location of the constituent morphemes in these items. In particular, the stem, which is important for accessing the word's meaning, is located at word beginning in suffixed items, but at word ending in prefixed items. Hence, when a left-to-right mechanism is at play (Kwantes & Mewhort, 1999), important information in suffixed items becomes accessible earlier in time than in prefixed items. Accordingly, we hypothesized that such mechanism is likely more pronounced in sentence reading than in single-word reading, because of the left-to-right nature of the former task. Thus, priming effects for suffixed items should be more robust than for prefixed items when the task involves sentence reading. We obtained similar results for prefixed and suffixed items with regards to the different prime type conditions, independently of task. Thus, our data do not seem to support the presence of a left-to-right processing mechanism during visual word recognition (see also Miller, Juhasz, & Rayner, 2006). However, it is worth noting that the absence of priming differences between prefixed and suffixed items could be due to the nature of the fast priming paradigm, which may have slightly delayed access to the target word, thus wiping out a potential processing advantage for suffixed items. In this paradigm, readers do not benefit from parafoveal preview of the target, as it is the case in the eye-contingent boundary paradigm, which as a result may weaken effects that occur very early in time (i.e., embedded stem activation). How could one explain then the discrepancy of the findings for prefixed and suffixed items in the literature? Morphological and orthographic variations across languages are thought to have an influence on derivational processing (Frost & Grainger, 2000; Verhoeven & Perfetti, 2011). Hence, some of the discrepancies between the different studies could be due to language differences. As far as German is concerned, both prefixes and suffixes occur equally frequently in the language, and are both easily identifiable when combined with stems, which may explain why German readers process them in a similar way.

Conclusion

In the present study, we investigated morphological processing both in single-word and sentence reading using the same experimental stimuli and comparable paradigms. We obtained an identical pattern of results for both prefixed and suffixed items across a variety of reading measures in both tasks. Our data suggest that skilled readers process embedded stems early during the reading process, independently of whether such stems are combined with an affix or a nonmorphological letter sequence. Further, our findings show that the same factors that underpin processing in single-word reading also operate in sentence reading, thus highlighting the need for more cross talk between these traditionally separate disciplines.

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(*Appendices follow*)

Appendix A

Items Used in Experiments 1a, 1b, and 3

Prime types					
realmorph	*pseudomorph*	*nonmorph*	*wordcontrol*	*nonwordcontrol*	Targets
Prefixed items					
ausblick	herblick	golblick	herwehen	golwehen	BLICK
ausbeute	einbeute	golbeute	einatmen	golatmen	BEUTE
aushilfe	einhilfe	kinhilfe	einbüßen	kinbüßen	HILFE
auslage	mitlage	kinlage	mitsamt	kinsamt	LAGE
ausrede	mitrede	kinrede	mitgift	kingift	REDE
auswahl	mitwahl	kinwahl	mitleid	kinleid	WAHL
ausmaß	mitmaß	golmaß	mithin	golhin	MAß
einband	hinband	karband	hinflug	karflug	BAND
einrad	hinrad	hemrad	hinweg	hemweg	RAD
einbaum	vorbaum	hembaum	vorbote	hembote	BAUM
einhorn	aushorn	karhorn	ausbund	karbund	HORN
eintopf	austopf	hemtopf	auslauf	hemlauf	TOPF
einwand	hinwand	karwand	hingabe	kargabe	WAND
eintracht	hintracht	hemtracht	hindürfen	hemdürfen	TRACHT
einklang	losklang	hemklang	losgehen	hemgehen	KLANG
eindruck	losdruck	hemdruck	loshexen	hemhexen	DRUCK
zuwachs	unwachs	emwachs	untiefe	emtiefe	WACHS
zustrom	unstrom	ogstrom	unschön	ogschön	STROM
zusage	unsage	ogsage	uncool	ogcool	SAGE
zulauf	unlauf	emlauf	unrast	emrast	LAUF
zugriff	ungriff	emgriff	unrecht	emrecht	GRIFF
zugabe	umgabe	emgabe	umlage	emlage	GABE
zufall	umfall	ogfall	umfang	ogfang	FALL
zudecke	umdecke	ogdecke	umstand	ogstand	DECKE
zuspruch	umspruch	emspruch	umkehren	emkehren	SPRUCH
zuflucht	umflucht	ogflucht	umfassen	ogfassen	FLUCHT
zugang	ungang	emgang	unfroh	emfroh	GANG
zuschuss	umschuss	ogschuss	umkippen	ogkippen	SCHUSS
unglück	umglück	emglück	umbauen	embauen	GLÜCK
ungnade	zugnade	emgnade	zunähen	emnähen	GNADE
unkraut	umkraut	lukraut	umarmen	luarmen	KRAUT
unlust	umlust	emlust	umgang	emgang	LUST
unrat	zurat	lurat	zuruf	luruf	RAT
unruhe	umruhe	luruhe	umraum	luraum	RUHE
undank	zudank	ludank	zuname	luname	DANK
unschuld	zuschuld	luschuld	zugleich	lugleich	SCHULD
unwetter	umwetter	luwetter	umhüllen	luhüllen	WETTER
unkosten	zukosten	emkosten	zunicken	emnicken	KOSTEN
umhang	unhang	luhang	unklar	luklar	HANG
umfeld	unfeld	ogfeld	unwahr	ogwahr	FELD
umfrage	zufrage	lufrage	zufügen	lufügen	FRAGE
umkreis	zukreis	lukreis	zutritt	lutritt	KREIS
umsicht	unsicht	ogsicht	untreue	ogtreue	SICHT
umsatz	unsatz	ogsatz	unklug	ogklug	SATZ
umschlag	unschlag	luschlag	ungeduld	lugeduld	SCHLAG
umtrunk	zutrunk	lutrunk	zufolge	lufolge	TRUNK
umwelt	zuwelt	ogwelt	zuerst	ogerst	WELT
vorbringen	losbringen	fosbringen	loswickeln	foswickeln	BRINGEN
vorführen	losführen	fosführen	loslassen	foslassen	FÜHREN
vorschlagen	hinschlagen	takschlagen	hinschicken	takschicken	SCHLAGEN
vordrängeln	ausdrängeln	fosdrängeln	aussprechen	fossprechen	DRÄNGELN
vorfinden	hinfinden	fosfinden	hinwerfen	foswerfen	FINDEN
vorheizen	hinheizen	takheizen	hinsetzen	taksetzen	HEIZEN
vorlesen	hinlesen	taklesen	hinlegen	taklegen	LESEN
vorschreiben	losschreiben	takschreiben	losschimpfen	takschimpfen	SCHREIBEN

(*Appendices continue*)

Appendix A (*continued*)

Prime types					
realmorph	*pseudomorph*	*nonmorph*	*wordcontrol*	*nonwordcontrol*	Targets
vorsagen	hinsagen	taksagen	hinsicht	taksicht	SAGEN
vortragen	lostragen	fostragen	losreißen	fosreißen	TRAGEN
vorsingen	lossingen	taksingen	losfahren	takfahren	SINGEN
mitfahren	herfahren	golfahren	herfallen	golfallen	FAHREN
mitgeben	losgeben	golgeben	loshaben	golhaben	GEBEN
mithelfen	vorhelfen	golhelfen	vorsprung	golsprung	HELFEN
mitlachen	vorlachen	epslachen	vorspeise	epsspeise	LACHEN
mitlaufen	herlaufen	epslaufen	hernieder	epsnieder	LAUFEN
mitreden	herreden	epsreden	herholen	epsholen	REDEN
mitreisen	vorreisen	epsreisen	vorposten	epsposten	REISEN
mitteilen	herteilen	golteilen	herhalten	golhalten	TEILEN
mitwirken	vorwirken	epswirken	vorbeugen	epsbeugen	WIRKEN
mitmachen	hermachen	golmachen	herzerren	golzerren	MACHEN
hinbiegen	ausbiegen	karbiegen	ausbeuten	karbeuten	BIEGEN
hinfallen	mitfallen	takfallen	mitweinen	takweinen	FALLEN
hingucken	eingucken	kargucken	einfärben	karfärben	GUCKEN
hinhalten	loshalten	takhalten	lostanzen	taktanzen	HALTEN
hinnehmen	losnehmen	taknehmen	losziehen	takziehem	NEHMEN
hinrennen	ausrennen	takrennen	ausbluten	takbluten	RENNEN
hinweisen	herweisen	karweisen	herräumen	karräumen	WEISEN
hinwollen	auswollen	karwollen	ausborgen	karborgen	WOLLEN
hindeuten	eindeuten	kardeuten	einkochen	karkochen	DEUTEN
losbinden	vorbinden	fosbinden	vorschule	fosschule	BINDEN
losdüsen	vordüsen	fosdüsen	vormonat	fosmonat	DÜSEN
loseisen	voreisen	kineisen	vorsehen	kinsehen	EISEN
loshasten	vorhasten	kinhasten	vorwerfen	kinwerfen	HASTEN
losheulen	einheulen	kinheulen	einpacken	kinpacken	HEULEN
loslegen	mitlegen	kinlegen	mitmalen	kinmalen	LEGEN
lostoben	eintoben	fostoben	einladen	fosladen	TOBEN
loswerden	einwerden	kinwerden	einmünden	kinmünden	WERDEN
losbrechen	vorbrechen	fosbrechen	vorschnell	fosschnell	BRECHEN
losbrüllen	vorbrüllen	fosbrüllen	vorspielen	fosspielen	BRÜLLEN
losrasen	vorrasen	fosrasen	vorsilbe	fossilbe	RASEN
lossausen	einsausen	kinsausen	einhüllen	kinhüllen	SAUSEN
herhören	einhören	epshören	einhaken	epshaken	HÖREN
herzwingen	mitzwingen	hemzwingen	mittreiben	hemtreiben	ZWINGEN
herlocken	auslocken	hemlocken	ausgießen	hemgießen	LOCKEN
herrufen	mitrufen	epsrufen	mithilfe	epshilfe	RUFEN
herbeten	ausbeten	epsbeten	auswuchs	epswuchs	BETEN
herflitzen	ausflitzen	epsflitzen	ausbreiten	epsbreiten	FLITZEN
herleiten	mitleiten	hemleiten	mitzählen	hemzählen	LEITEN
hertrauen	austrauen	hemtrauen	ausgraben	hemgraben	TRAUEN
herjagen	ausjagen	epsjagen	ausstieg	epsstieg	JAGEN
herrühren	ausrühren	hemrühren	ausharren	hemharren	RÜHREN
herstellen	mitstellen	hemstellen	mitfliegen	hemfliegen	STELLEN
Suffixed items					
krampfhaft	krampflein	krampfnauf	mütterlein	mütternauf	KRAMPF
ruckhaft	ruckheit	ruckucht	feigheit	feigucht	RUCK
ernsthaft	ernstlein	ernstnauf	bäuchlein	bäuchnauf	ERNST
traumhaft	traumlein	traumucht	tischlein	tischucht	TRAUM
sprunghaft	sprunglein	sprungucht	fröschlein	fröschucht	SPRUNG
ekelhaft	ekelheit	ekelnauf	geilheit	geilnauf	EKEL
zwanghaft	zwangheit	zwangucht	sanftheit	sanftucht	ZWANG
scherzhaft	scherzlein	scherzucht	fläschlein	fläschucht	SCHERZ
spaßhaft	spaßheit	spaßucht	klugheit	klugucht	SPAß
herzhaft	herzheit	herznauf	sturheit	sturnauf	HERZ
holzig	holzin	holzam	hirtin	hirtam	HOLZ
fruchtig	fruchtin	fruchtam	pastorin	pastoram	FRUCHT

(*Appendices continue*)

Appendix A (*continued*)

Prime types					
realmorph	*pseudomorph*	*nonmorph*	*wordcontrol*	*nonwordcontrol*	Targets
gelenkig	gelenkin	gelenkam	expertin	expertam	GELENK
glasig	glasin	glasam	köchin	köcham	GLAS
haarig	haarin	haaram	gräfin	gräfam	HAAR
schmutzig	schmutzin	schmutzam	bischöfin	bischöfam	SCHMUTZ
kernig	kernin	kernam	ärztin	ärztam	KERN
matschig	matschin	matscham	juristin	juristam	MATSCH
mutig	mutin	mutam	erbin	erbam	MUT
schaumig	schaumin	schaumam	kollegin	kollegam	SCHAUM
geruchlos	geruchung	geruchekt	fälschung	fälschekt	GERUCH
fristlos	fristnis	fristmen	erlebnis	erlebmen	FRIST
kampflos	kampfung	kampfekt	richtung	richtekt	KAMPF
ratlos	ratnis	ratmen	wagnis	wagmen	RAT
sinnlos	sinnung	sinnekt	nutzung	nutzekt	SINN
wertlos	wertnis	wertekt	bündnis	bündekt	WERT
bartlos	bartung	bartmen	meldung	meldmen	BART
ruhelos	ruhenis	ruhemen	bildnis	bildmen	RUHE
ziellos	zielnis	zielmen	zeugnis	zeugmen	ZIEL
zwecklos	zweckung	zweckekt	leistung	leistekt	ZWECK
athletisch	athlethaft	athleticht	schalkhaft	schalkicht	ATHLET
diebisch	diebchen	diebtern	deckchen	decktern	DIEB
neidisch	neidchen	neidtern	bierchen	biertern	NEID
typisch	typhaft	typicht	erdhaft	erdicht	TYP
militärisch	militärhaft	militärtern	vorteilhaft	vorteilpern	MILITÄR
metallisch	metallchen	metallicht	scheibchen	scheibicht	METALL
rebellisch	rebellchen	rebellicht	schätzchen	schätzicht	REBELL
schelmisch	schelmhaft	schelmtern	fieberhaft	fiebertern	SCHELM
spöttisch	spottchen	spotticht	tröpfchen	tröpficht	SPOTT
höhnisch	hohnhaft	hohntern	lachhaft	lachtern	HOHN
schriftlich	schriftlein	schriftpern	schwälblein	schwälbpern	SCHRIFT
fachlich	fachlein	fachpern	händlein	händpern	FACH
festlich	festhaft	festpern	tierhaft	tierpern	FEST
schrecklich	schrecklein	schreckpern	schwertlein	schwertpern	SCHRECK
weiblich	weibhaft	weibpfen	sieghaft	siegpfen	WEIB
göttlich	göttlein	göttpfen	küchlein	küchpfen	GOTT
heimatlich	heimathaft	heimatpfen	grauenhaft	grauenpfen	HEIMAT
mündlich	mündhaft	mündpfen	wahnhaft	wahnpfen	MUND
künstlich	künsthaft	künstpern	fabelhaft	fabelpern	KUNST
glücklich	glücklein	glückpfen	brünnlein	brünnpfen	GLÜCK
hemdchen	hemdlich	hemdnauf	fraglich	fragnauf	HEMD
löffelchen	löffelheit	löffelicht	gesundheit	gesundicht	LÖFFEL
bärchen	bärlich	bäricht	gütlich	güticht	BÄR
engelchen	engelheit	engelicht	frechheit	frechicht	ENGEL
fischchen	fischlich	fischicht	dringlich	dringicht	FISCH
türchen	türlich	türnauf	löblich	löbnauf	TÜR
krümelchen	krümelheit	krümelnauf	sicherheit	sichernauf	KRÜMEL
spielchen	spielheit	spielnauf	dumpfheit	dumpfnauf	SPIEL
brettchen	brettlich	bretticht	glaublich	glaubicht	BRETT
zettelchen	zettelheit	zettelnauf	gleichheit	gleichnauf	ZETTEL
feindin	feindig	feindau	buschig	buschau	FEIND
fürstin	fürstig	fürstau	demütig	demütau	FÜRST
piratin	piratig	piratau	dreckig	dreckau	PIRAT
wirtin	wirtig	wirtau	leidig	leidau	WIRT
anwältin	anwältig	anwältau	geduldig	geduldau	ANWALT
freundin	freundig	freundau	flüchtig	flüchtau	FREUND
heldin	heldig	heldau	narbig	narbau	HELD
herrin	herrig	herrau	heutig	heutau	HERR
baronin	baronig	baronau	apfelig	apfelau	BARON
autorin	autorig	autorau	milchig	milchau	AUTOR
blindheit	blindchen	blindpfen	flittchen	flittpfen	BLIND
kühnheit	kühnisch	kühnucht	kölnisch	kölnucht	KÜHN

(*Appendices continue*)

Appendix A (*continued*)

Prime types					
realmorph	*pseudomorph*	*nonmorph*	*wordcontrol*	*nonwordcontrol*	Targets
dummheit	dummisch	dummucht	biblisch	biblucht	DUMM
blödheit	blödchen	blödpfen	laibchen	laibpfen	BLÖD
freiheit	freichen	freipfen	küsschen	küsspfen	FREI
stummheit	stummisch	stummucht	praktisch	praktucht	STUMM
klarheit	klarchen	klarucht	päckchen	päckucht	KLAR
schönheit	schönisch	schönpfen	organisch	organpfen	SCHÖN
weichheit	weichisch	weichucht	politisch	politucht	WEICH
bettlein	bettlich	bettpern	peinlich	peinpern	BETT
menschlein	menschisch	menschtern	symbolisch	symboltern	MENSCH
kindlein	kindhaft	kindpern	sündhaft	sündpern	KIND
liedlein	liedlich	liedpern	gelblich	gelbpern	LIED
männlein	männheit	männpern	reinheit	reinpern	MANN
bäumlein	bäumisch	bäumpern	launisch	launpern	BAUM
säcklein	säckheit	säcktern	grobheit	grobtern	SACK
schifflein	schiffisch	schifftern	gigantisch	giganttern	SCHIFF
fräulein	fräuheit	fräupern	taubheit	taubpern	FRAU
büchlein	büchlich	büchtern	gastlich	gasttern	BUCH
ringlein	ringisch	ringtern	närrisch	närrtern	RING
teilung	teilnis	teilmen	säumnis	säummen	TEIL
bergung	berglos	bergmen	farblos	farbmen	BERG
haftung	haftlos	haftmen	hilflos	hilfmen	HAFT
zeitung	zeitnis	zeitmen	fäulnis	fäulekt	ZEIT
zahlung	zahlnis	zahlmen	wirrnis	wirrekt	ZAHL
grabung	grablos	grabekt	restlos	restekt	GRAB
kleidung	kleidlos	kleidekt	drahtlos	drahtekt	KLEID
kreuzung	kreuzlos	kreuzekt	kraftlos	kraftekt	KREUZ
planung	plannis	planekt	trübnis	trübekt	PLAN
blutung	blutnis	blutekt	hemmnis	hemmekt	BLUT

Note. The targets in experiment 3 consisted of the primes in the realmorph condition.

(*Appendices continue*)

Appendix B

Items Used in Experiment 2

	Sentences in the prefixed condition
1	Klara bestaunte den weiten Ausblick lange.
2	Klaus fand die heutige Ausbeute zufriedenstellend.
3	Peter konnte eine neue Aushilfe gut gebrauchen.
4	Gerd starrte die reiche Auslage im Geschäft an.
5	Diese dreiste und dumme Ausrede glaubte Horst nicht.
6	Leider war die heutige Auswahl nicht sehr groß.
7	Alina konnte das ganze Ausmaß nicht fassen.
8	Max streichelte den alten Einband und öffnete das Buch.
9	Hans wollte schon immer Einrad fahren.
10	Der lange und schlanke Einbaum trieb den Fluss hinab.
11	Ariana ritt das weiße Einhorn sehr elegant.
12	Kevin war der russische Eintopf gut gelungen.
13	Igor fand den klugen Einwand berechtigt.
14	Abends tranken sie voller Eintracht noch ein Glas Wein.
15	Sie lebten im schönsten Einklang bis an ihr Lebensende.
16	Ivo wollte einen guten Eindruck hinterlassen.
17	Karl wollte den jährlichen Zuwachs noch steigern.
18	Sie wollten den starken Zustrom reduzieren.
19	Toni erwartet die schriftliche Zusage jeden Tag.
20	Die Show hatte großen Zulauf und war beliebt.
21	Polizisten übten den raschen Zugriff bei einem Überfall.
22	Astrid wollte die nächste Zugabe nur für ihn singen.
23	Es war ein großer Zufall und keiner hat das erwartet.
24	Anna wollte die schwere Zudecke aus dem Bett werfen.
25	Martins Rede erhielt großen Zuspruch von allen.
26	Das war Oskars letzte Zuflucht und Hoffnung.
27	Gestern war der enge Zugang verstopft.
28	Berta brauchte einen großen Zuschuss für ihre Miete.
29	Bettina hatte das schwere Unglück überlebt.
30	Rolf drohte in königliche Ungnade zu fallen.
31	Stefan vernichtete das dichte Unkraut mit einer Sense.
32	Doris empfand eine große Unlust bei dem Gedanken.
33	Der Hof war voller Unrat und Müll.
34	Tom war in ständiger Unruhe seit seinem Unfall.
35	Natürlich war nur grober Undank ihr Lohn dafür.
36	Uwe bewunderte die kindliche Unschuld des Jungen.
37	Plötzlich kam ein schweres Unwetter über das Land.
38	Sie würden die hohen Unkosten tragen müssen.
39	Walter fand den schwarzen Umhang etwas gruselig.
40	Nur in seinem nächsten Umfeld zeigte man Verständnis.
41	Lotte wollte die nächste Umfrage schon bald machen.
42	Es gab im nahen Umkreis keinen einzigen Kindergarten.
43	Herta verfolgte mit großer Umsicht ihre Ziele.
44	Sie machten ihren gesamten Umsatz durch Aktien.
45	Thorsten öffnete den großen Umschlag hastig.
46	Imke wollte einen kleinen Umtrunk veranstalten.
47	Isabell wollte eine saubere Umwelt und kämpfte dafür.
48	Karin würde die Klage vorbringen und Recht bekommen.
49	Lea wollte den Film vorführen und kommentieren.
50	Bernd wollte ihnen nichts vorschlagen oder befehlen.
51	Mia wollte sich schnell vordrängeln und ging los.
52	Was würden sie dort vorfinden und entdecken?
53	Leopold würde die Wohnung vorheizen lassen.
54	Nadine sollte das Buch vorlesen und fing an.
55	Christian konnte ihr nichts vorschreiben oder verbieten.
56	Ruth wollte die Lösung vorsagen in der nächsten Stunde.
57	Timo würde sein Gedicht vortragen und gewinnen.
58	Sofia wollte ein Lied vorsingen und sich selbst begleiten.

(*Appendices continue*)

Appendix B (*continued*)

59	Die Mutter wollte nicht mitfahren und blieb zu Hause.
60	Ulla wollte ihnen nichts mitgeben und ging.
61	Die Nonne wollte wieder mithelfen und Gutes tun.
62	Xenia konnte nur gespielt mitlachen und weiterreden.
63	Bald würde Yvonne wieder mitlaufen und gewinnen.
64	Da wollte Renate aber mitreden und Einfluss nehmen.
65	Thomas will uns noch mitreisen lassen.
66	Das wollte er Petra mitteilen bevor er ging.
67	Volker wollte am Film mitwirken und die Rolle bekommen.
68	Zora würde jeden Streich mitmachen und ihnen helfen.
69	Das würde der Anwalt hinbiegen können.
70	Wo die nächste Bombe hinfallen würde, wusste Erich nicht.
71	Paul wollte gar nicht hingucken und fürchtete sich.
72	Susanne wollte Niklas nicht hinhalten und rief ihn an.
73	Mirko wollte das nicht hinnehmen und schwor Rache.
74	Da werde ich sofort hinrennen und nachsehen!
75	Der Vater wollte darauf hinweisen und Monika warnen.
76	Morgen werden sie irgendwo hinwollen und losfahren.
77	Alles würde auf Regina hindeuten und sie belasten.
78	Er wollte Rosa schnell losbinden und befreien.
79	Jetzt wollte der Junge losdüsen und alles erzählen.
80	Mario konnte sich nicht loseisen und blieb auf der Party.
81	Jetzt musste Pia schnell loshasten und sich beeilen.
82	Selma wollte jetzt einfach losheulen und sich verstecken.
83	Jetzt müssen wir aber loslegen und uns beeilen.
84	Die Kinder wollten wieder lostoben und spielen.
85	Marco wollte das Problem loswerden und verdrängen.
86	Nina wollte keinen Skandal losbrechen und ihn verletzen.
87	Der Löwe würde einfach losbrüllen und sie vertreiben!
88	Der Fahrer würde einfach losrasen und sie alle abhängen.
89	Der Bote wird sofort lossausen und ihnen berichten.
90	Die Schüler wollten nicht herhören und leise sein.
91	Otto konnte sie nicht herzwingen und musste warten.
92	Der Geist wollte Maria herlocken und erschrecken.
93	Kai wollte sie wieder herrufen und nachfragen.
94	Fritz konnte den Stoff herbeten und war bereit.
95	Emil würde sicher direkt herflitzen und berichten.
96	Josef musste die Lösung herleiten und begann zu rechnen.
97	Lilli würde sich nicht hertrauen und sie meiden.
98	Jan wollte den Hirsch herjagen und fangen!
99	Von einem schweren Schlag herrühren konnte die Wunde auch.
100	Lisa wollte die Medizin herstellen und verkaufen.

Sentences in the suffixed condition

1	Bettina lachte ein wenig krampfhaft und hustete.
2	Der intelligente Roboter sprach ruckhaft und abgehakt.
3	Sein Mut konnte nicht ernsthaft bezweifelt werden.
4	Das Hotelzimmer war einfach traumhaft schön.
5	Normalerweise war Tom ziemlich sprunghaft und spontan.
6	Die Suppe schmeckte absolut ekelhaft und war total versalzen.
7	Sein Verhalten wirkte etwas zwanghaft und verkrampft.
8	Die Ansprache war sicher scherzhaft gemeint gewesen.
9	Immer wieder dachte Claudia spaßhaft an den Urlaub.
10	Sie lachte und biss herzhaft in ihr Brötchen.
11	Der Wald roch angenehm holzig und frisch.
12	Der italienische Wein schmeckte fruchtig und erfrischend.
13	Der Akrobat war sehr gelenkig und gut trainiert.
14	Ralphs Augen wurden plötzlich glasig und er brach zusammen.
15	Die Spinnenbeine waren furchtbar haarig und lang.
16	Die Wohnung war sehr schmutzig und verstaubt.
17	Großmutter sah wie immer kernig und gesund aus.
18	Die meisten Äpfel lagen matschig auf dem Boden.
19	Das war wirklich sehr mutig von ihr gewesen.

(*Appendices continue*)

Appendix B (*continued*)

20	Peter schlug drei Eigelb schaumig und kostete den Teig.
21	Das Gas ist vollkommen geruchlos und deswegen gefährlich.
22	Der neue Kellner wurde fristlos entlassen.
23	Thorsten wollte sich nicht kampflos geschlagen geben.
24	Die erstaunte Lehrerin schaute ratlos die Mutter an.
25	Die ganze Gruppe rannte sinnlos umher.
26	Klaus fühlt sich häufig wertlos und klein.
27	Ihre toten Gesichter waren bartlos und blass.
28	Nachts wälzte sich Julia ruhelos in ihrem Bett herum.
29	Sein Handeln war seltsam ziellos und unüberlegt.
30	Der Versuch war vollkommen zwecklos und umsonst.
31	Ihr ganzer Körper wirkte athletisch und durchtrainiert.
32	Der gemeine Mörder lächelte diebisch und drückte ab.
33	Nadine schaute ihren Bruder neidisch an.
34	Dieses Verhalten war leider typisch für ihn.
35	Horst trug sein Haar militärisch kurz.
36	Irgendwie klang seine Stimme metallisch und seltsam fremd.
37	Heute war die Klasse rebellisch und störte andauernd.
38	Der verwegene Matrose lächelte schelmisch und winkte.
39	Die fremde Frau blickte spöttisch auf sie herab.
40	Der böse Räuber lachte höhnisch und spuckte aus.
41	Das wird er morgen schriftlich bekommen.
42	Sein Verhalten war stets fachlich einwandfrei und korrekt.
43	Der große Saal leuchtete festlich im Kerzenlicht.
44	Die Situation war einfach schrecklich und bedrohlich.
45	Seine schlanken Hände waren weiblich und gut gepflegt.
46	Der Schokoladenkuchen war einfach göttlich lecker.
47	Die Stimmung war abends heimatlich und ein wenig traurig.
48	Viele wichtige Verträge werden mündlich geschlossen.
49	Der rote Saft schmeckte künstlich und war zu süß.
50	Der alte Schäfer summte glücklich vor sich hin.
51	Das weiße und verschwitzte Hemdchen klebte auf ihrer Haut.
52	Leider waren die silbernen Löffelchen viel zu teuer gewesen.
53	Die roten und grünen Bärchen sind besonders lecker.
54	Martin war ein richtiges Engelchen als Kind gewesen.
55	Gestern schwamm das kleine Fischchen ins Meer hinaus.
56	Er öffnete das letzte Türchen des Adventskalenders.
57	Natürlich blieb kein einziges Krümelchen übrig.
58	Lisa mochte dieses dreckige Spielchen nicht.
59	Ich habe das neue Brettchen gestern noch gesehen.
60	Er benutzte ein kleines Zettelchen für die Nachricht.
61	Melanie war ihre erbitterte Feindin gewesen.
62	Gnadenlos herrschte die grausame Fürstin über ihr Reich.
63	Zora war eine stolze Piratin und sehr gefährlich.
64	Die nette, aber vergessliche Wirtin hatte ihn nicht geweckt.
65	Wahrscheinlich hatte die junge Anwältin einen Fehler gemacht.
66	Eva war ihre beste Freundin und Vertraute.
67	Silvia war eine echte Heldin und wurde gefeiert.
68	Manchmal war die junge Herrin unberechenbar.
69	Täglich ritt die alte Baronin auf ihrem Pferd aus.
70	Später wollte Alina einmal Autorin werden.
71	Max war die totale Blindheit inzwischen gewöhnt.
72	Für einen Ritter sind Kühnheit und Wagemut sehr wichtig.
73	Das war eine große Dummheit gewesen.
74	Klaus hatte aus reiner Blödheit seinen Vertrag gekündigt.
75	Lasst uns für unsere Freiheit kämpfen!
76	Ihre unheimliche und traurige Stummheit hatte ihn berührt.
77	Darüber wollte er sich Klarheit verschaffen.
78	Hohes Alter und große Schönheit wünschen sich alle.
79	Christina überraschte die dunkle Weichheit seiner Stimme.
80	Wer hat in meinem Bettlein geschlafen?
81	Heute wollte das kleine Menschlein Pilze pflücken gehen.
82	Erschrocken schaute das brave Kindlein den Nikolaus an.

(*Appendices continue*)

Appendix B (*continued*)

83	Peter pfiff ein lustiges Liedlein und freute sich.
84	Sorgenvoll betrachtete das kleine Männlein den Himmel.
85	Irgendwann wächst jedes schwache Bäumlein zum Baum heran.
86	Er wog das kleine Säcklein in der Hand.
87	Er schob das kleine Schifflein in die Flasche.
88	Das hübsche und nette Fräulein an der Theke lächelte.
89	Sie schloss das schwarze Büchlein und steckte es ein.
90	Sicher hatte das magische Ringlein große Kräfte.
91	Nach der langen, gewaltsamen Teilung wuchs das Land zusammen.
92	Max leitete die gefährliche Bergung professionell.
93	Eltern übernehmen die rechtliche Haftung für ihre Kinder.
94	Sie hatte die alte Zeitung noch nicht weggeworfen.
95	Gerd erwartete die letzte Zahlung jeden Tag.
96	Die beschwerliche und teure Grabung war ein voller Erfolg.
97	Alice hatte immer warme Kleidung in ihrem Rucksack dabei.
98	An der zweiten großen Kreuzung sollte sie rechts abbiegen.
99	Durch die gründliche, lange Planung war die Aktion gelungen.
100	Er hatte die tödliche Blutung nicht stoppen können.

Received October 11, 2017
Revision received March 26, 2018
Accepted March 29, 2018 ■