The influence of morphological structure on the processing of German prefixed verbs

Judith Heide, Antje Lorenz, André Meinunger and Frank Burchert

1. Introduction

..1 Polymorphemic words in the Mental Lexicon

One of the central issues in psycholinguistic research is how words are represented, accessed, and processed in a speaker's mind. The Mental Lexicon, i.e., the dynamic organization of words in long-term memory, is a vast and complex network of mental representations, associations, and processes which ensures the great speed and automaticity of word recognition and production in everyday language use.

One field of research on the Mental Lexicon centres around the question how morphologically complex words are represented and accessed. Taft and Forster (1975) were the first to show that complex words are decomposed into their constituent morphemes in language recognition and that affixes and stems may have distinct mental representations (see also Taft 1986, 1988, 2004, Taft, Hambly and Kinoshita 1986). However, other authors argue for a holistic representation of polymorphemic words (Manelis and Tharp 1977; Butterworth 1983, Bybee 1995, Rumelhart and McClelland 1986, Sereno and Jongman 1997, Plaut and Gonnerman 2000), and there is no unequivocal evidence for either models of decomposition or full-listing approaches. Current psycholinguistic models therefore postulate dual routes or dual mechanisms to allow for both morphological decomposition and full form processing (e.g., Caramazza, Laudanna and Romani 1988, Pinker and Prince 1994, Baayen and Schreuder 1999, Clahsen, Sonnenstuhl and Blevins 2003). Various psycholinguistic parameters such as regularity, semantic transparency, and frequency are assumed to influence the processing of polymorphemic words, and there is evidence that irregular, opaque, and high-frequent words are listed as full forms in the mental lexicon while regular, transparent, and low-frequent words undergo morphological decomposition (Bertram, Schreuder and Baayen 2000, Baayen, McQueen, Dijkstra and Schreuder 2003).

The dual mechanism account has been applied to the German Mental Lexicon by Clahsen and colleagues for inflectional (Clahsen, Eisenbeiss and Sonnenstuhl 1997, Sonnenstuhl, Eisenbeiss and Clahsen 1999, Sonnenstuhl and Huth 2002) and derivational processes (Sonnenstuhl and Huth 2002, Clahsen et al. 2003). To account for the different experimental findings on German inflection and derivation, Clahsen et al. (2003) suggest a refined version of the dual mechanism approach. The authors argue that regular inflected words are decomposable into stem and affix (and are, therefore, sensitive to root priming) while irregular inflected words match holistic entries (and thus show an effect of full form frequency). In the case of derived words (nominalizations and diminutives), both an effect of root priming and of full form frequency was observed (Clahsen et al. 2003). This led the authors to the conclusion that derived words are represented as full forms in the mental lexicon, but that they are linked to the underived stem form. However, as Clahsen et al. (2003) only used suffixed words in their experiments, it remains an open question whether the assumption of a "linked full form representation" for derived words is specific to suffixation or whether it holds for prefixed items, too.

Literature on (German) word formation takes different views on the relationship between prefixation and suffixation. In contrast to Olsen (1986) and Erben (2000), for example, who argue that both suffixation and prefixation are derivational processes, Fleischer (1982) highlights the differences between suffixation and prefixation. He concludes that only suffixation is a derivational word formation process, but that prefixation has to be regarded as a third word formation process aside from compounding and derivation. Thus, from a theoretical perspective, it cannot be easily decided whether the results of Clahsen et al. (2003) for suffixed words are extendable to prefixation. Therefore, the aim of the present study is to investigate how prefixed words are represented and processed in the Mental Lexicon. Specifically, we focus on German verbs which are prefixed with *ver-* (e.g., *verlaufen* 'to get lost'). The linguistic properties of these verbs are described in the following section.

..2 Linguistic properties of German *ver*-prefixed verbs

Together with *be-*, *ent-*, *er-*, and *zer-*, the prefix *ver-* is one of the central German prefixes which form morphologically complex verbs by derivation from different roots. Unlike most other prefixes in German, these prefixes are usually unstressed (except for contrastive contexts) and immobile, i.e., they cannot be separated from their root in a sentence context as shown in 1 and 2. Thus, it is not trivial to ask whether these prefixes may have separate mental representations.

1. vergében
   a. ✓Ich *vergebe* Dir
   b. *Ich *gebe* Dir *ver*
      I forgive you
2. ábgeben
   a. *Ich *abgebe* etwas
   b. ✓Ich *gebe* etwas *ab*
      I hand something in

Among the central prefixes, *ver-* represents the biggest group with 693 verbs (CELEX database, Baayen, Piepenbrock and Gulikers 1995). Pseudo-prefixed verbs are very few in number. These are verbs beginning with the letter triplet *ver-* and with *ver-* being no prefix (e.g., *verbalisieren* 'to verbalize'). Because of this numerical salience and the limited risk of misparsings, *ver*-prefixed verbs should have prominent mental representations which can be parsed efficiently (Schirmeier 2004).

Initially, all *ver*-verbs seem to form a homogenous group. They consist of the prefix *ver-*, a root, and the infinitival suffix *(e)n,*[1] resulting in a ver+ root+(e)n surface structure (e.g., *verlaufen* ~ *ver+lauf+en*). However, the internal structure of these items may differ considerably. First, the root type varies, as the prefix *ver-* can be added to nouns (*Schlüssel* 'key' → *verschlüsseln* 'to encode'), verbs (*laufen* 'to walk' → *verlaufen* 'to get lost'), adjectives (*blass* 'pale' → *verblassen* 'to fade'), and bound morphemes (**gess(en)* → *vergessen* 'to forget').[2] For most words, the root can be identified unambiguously. However, in some instances it remains unclear whether the prefixed verb (e.g., *verlieben* 'to fall in love') was derived from a noun (*Liebe* 'love') or from a verb (*lieben* 'to love') (for a further discussion of this issue see Umbreit, this volume). More generally, one can distinguish between *ver*-prefixed verbs derived from a lexical root (verb, noun, and adjective) and verbs containing a non-lexical root, i.e., a bound morpheme.

Second, some *ver*-prefixed verbs do not seem to follow the *Righthand Head Rule* (RHR, Williams 1981, cf. Donalies 2007: 21f.). The RHR states that the righthand constituent of a morphologically complex word is the head of that word and determines the lexical category of the full form. By definition, prefixes are added to the left side of a root, they do not change its lexical category but alter or specify the meaning (Fleischer, 1982). This would mean that the prefix *ver-* should be added to a (simple) verb, which then constitutes the righthand constituent of the morphologically complex word and determines that the prefixed item, too, belongs to the lexical category of verbs. This analysis is uncontroversial for those *ver*-prefixed verbs which were derived from a simple verb (e.g., *verlaufen*). However, verbs like *verschlüsseln*, *verblassen*, and *vergessen* are analyzed as being derived from a noun, an adjective, and a bound morpheme because the rightmost element does not form an existing German verb (**schlüsseln, *blassen, *gessen*). In these cases, it seems to be the prefix, i.e., the lefthand element, which determines the syntactic properties of the full form. Olsen (1991) suggests that the prefix is the head of the complex verb and provides syntactic information of the full form (e.g., *verschlüsseln* begins with *ver-* and is therefore a verb although it is derived from a noun). However, violating the RHR might not be necessary: One possibility to account for a verb like *verschlüsseln* is to assume a virtually existing verb *schlüsseln* to which the prefix *ver-* is attached. This, however, implies a two-stage derivation process involving a non existing intermediate form (Plank 1981). Alternatively, following Fleischer and Barz (1995), two derivational processes may apply to a root like *Schlüssel* simultanously by adding the prefix and changing the lexical category at the same time. In such a case, a special word formation type "prefix conversion" must be postulated. Finally, it is possible to derive verbs like *verschlüsseln* and *verblassen* by circumfixation. Here, prefix and suffix form a discontinuous affix and are added to the root simultaneously. Circumfixation is well described for the formation of the German past participle, and Drijkoningen (1999) shows how the RHR is capable of explaining circumfixation. For the case of *ver-*prefixed verbs, though, one would need to specify whether all verbs are derived by circumfixation or whether some verbs are prefixed and others are circumfixed.

Irrespective of the theoretical explanation, it is obvious that for some *ver*-prefixed verbs the combination of root+(e)n corresponds to an existing German verb (e.g., *laufen* in *verlaufen*), while in other cases the root+(e)n combination is non-lexical (e.g., **schlüsseln* in *verschlüsseln*).[3]

Finally, the prefix *ver-* can bear different semantic properties and can change the meaning of the root accordingly. Fleischer and Barz (1995) distinguish three main types of *ver*-prefixed verbs: *perfective* verbs indicate the gradual completion of a process (e.g., *verheilen* 'to heal'). A *modal* reading implies that the action is performed incorrectly (*verlaufen* 'to get lost') or too excessively (*versalzen* 'to oversalt').[4] In an *intensive* reading, the prefixation with *ver-* results in an intensification of root meaning (*verbleiben* 'to remain'). In addition, the semantic transparency of the prefixed verb varies, i.e., the extent to which the meaning of the root is still recognizable in the meaning of the full form. While the meaning of a (perfective) verb like *verarmen* ('to impoverish') is accessible via the combined meaning of the prefix and the root (*arm* 'poor'), this is not true for a verb like *vertragen* ('to tolerate'), which is derived from *tragen* ('to carry'). The concept of semantic transparency does not apply to verbs derived from a bound pseudo-morpheme as the latter do not have any meaning in modern German.

As shown above, although *ver*-prefixed verbs have the common surface structure ver+root+(e)n and seem to form a homogenous group, subsets differ considerably with respect to (a) the lexical category of the root (root type), (b) the lexicality of the root, (c) the lexicality of the root+(e)n combination, and (d) the semantic transparency of the full form. Table 1 summarizes the linguistic properties of German *ver*-prefixed verbs and gives an overview of the existing subsets.

<table>
<tr><td rowspan="3">morphological structure</td><td>root type</td><td>verb</td><td>noun/ verb</td><td>noun</td><td>adjective</td><td>bound</td></tr>
<tr><td>lexicality of the root</td><td colspan="4">lexical</td><td>non lexical
vergessen
to forget
*gess</td></tr>
<tr><td>lexicality of root+(e)n</td><td colspan="2">lexical</td><td colspan="2">non lexical</td><td>non lexical
vergessen
to forget
*gessen</td></tr>
<tr><td rowspan="3">semantic transparency</td><td>fully trsp.</td><td>vermischen
to mix
misch mix
mischen
to mix</td><td>verlieben
to fall in love
Liebe love
lieben
to love</td><td>vergiften
to poison
Gift poison
*giften</td><td>verstummen
to fall silent
stumm mute
*stummen</td><td>n.a.</td></tr>
<tr><td>semi trsp.</td><td>verzeichnen
to register
zeichne sketch
zeichnen
to sketch</td><td>verschleudern
to squander
Schleuder
sling
schleudern
to sling</td><td>verteufeln
to demonise
Teufel devil
*teufeln</td><td>versauern
to go stale
sauer sour
*sauern</td><td>n.a.</td></tr>
<tr><td>opaque</td><td>verstehen
to understand
steh stand
stehen to stand</td><td>verraten
to betray
Rat advice
raten to advise</td><td>vermuten
to assume
Mut courage
*muten</td><td>vereiteln
to foil
eitel vain
*eiteln</td><td>n.a.</td></tr>
</table>

Table 1. Overview of the linguistic properties of German verbs prefixed with ver-. (n. a.: not applicable)

2. Morphological priming of *ver*-prefixed verbs: The study of Schirmeier, Derwing, and Libben (2004)

In a recent study, Schirmeier, Derwing and Libben (2004) investigated whether the Mental Lexicon contains any morphological links between a *ver*-prefixed verb (the full form) and its constituents (prefix, root, and suffix). They used a lexical decision paradigm and applied visual morphological priming to 72 *ver*-prefixed verbs which were either derived from a verb, a noun, an adjective, or a bound morpheme. The target items (e.g., *verbittern* 'to embitter') were preceded by either a related or neutral root prime (BITTER/ SAUBER) or a related or a neutral root+(e)n prime (BITTERN/ SAUBERN). For all root types, response latencies were shorter in the related than in the neutral root priming condition. However, the amount of the priming effect was bigger for *ver*-verbs derived from adjectives and nouns than for full forms containing a verbal or a bound root. Root+(e)n priming showed to be equally effective for all four subsets. Thus, for the verb and bound group, root+(e)n priming was more effective than root priming, while the opposite was the case for *ver*-verbs derived from adjectives, and there was no difference for the noun subset. In addition, a comparison of the different root types in both neutral priming conditions showed elevated response latencies for the adjective subset although the subsets had been matched carefully for factors known to affect lexical decision latencies.

Schirmeier et al. (2004) explain their results in terms of the psycholinguistic parameters "lexicality" and "morphological structure". According to the authors, lexicality accounts for the fact that the adjective subset benefits more from root than from root+(e)n priming, whereas the verb subset shows bigger effects for root+(e)n than for root priming. While this explanation is convincing for *ver*-verbs derived from an adjective, as their root in contrast to the root+(e)n combination represents a lexical entry, it is less plausible for items derived from a verb. In the latter case, both root and root+(e)n are lexical (the root being the familiar imperative and root+(e)n the infinitive). So, either prime frequency (as the infinitive form root+(e)n is likely to be more frequent than the imperative root) or the extent of visual overlap of prime and target, which is bigger in the case of root+(e)n, may account for the difference found. It also remained unclear whether the (non)-lexicality of a full form's root has an influence on the processing of the whole word. On the one hand, stimuli with a bound root showed only a small root priming effect, which, according to Schirmeier et al., "confirms [their] prediction of an effect of root lexicality in the priming study" (2004: 78). On the other hand, in the neutrally primed conditions, stimuli with a bound root were not recognized more slowly than those with a lexical root and the authors conclude that "whether or not the root is a real word does not seem to affect whole-word processing" (2004: 85). Thus, the results of Schirmeier et al. (2004) cannot entirely answer the question whether lexicality has an impact on the processing of the prefixed verb.

Furthermore, if lexicality alone influenced the processing of the full form, one would, according to Schirmeier et al. (2004), expect equal effects of root and root+(e)n priming for items with a bound root because with these items both root and root+(e)n are non-lexical. By contrast, the noun subset should have been primed better by the (lexical) root than by the (non-lexical) root+(e)n combination. As this was not the case, Schirmeier et al. (2004) introduce morphological structure as a second parameter supposedly influencing the processing of the full form. Schirmeier et al. (2004) argue that the default morphological structure for *ver*-prefixed verbs is right-branching ([ver]+root+(e)n]). This applies to verbs derived from verbs, bound roots, and nouns, as for these subsets root+(e)n priming showed to be more effective than root priming. For the adjectival subset, however, priming with a root was more effective than priming with root+(e)n, which Schirmeier et al. explain with the "structural anomalousness" of these items (2004: 85).

Although the idea that the internal morphological structure may influence the processing of a morphologically complex full form is promising, the interpretation and conclusion of Schirmeier et al. (2004) are somewhat problematic. The authors state that *ver*-prefixed verbs derived from an adjective (e.g., *verarmen*) are „structurally anomalous", presumably because they contain a lexical root (*arm*) but also a non-lexical morphological substring (**armen*). However, this is also true for *ver*-verbs derived from a noun (e.g., *verschlüsseln* 'to encode') with *Schlüssel* ('key') as the lexical root, while the substring **schlüsseln* does not exist.[5] Furthermore, the items used in Schirmeier et al. (2004) in the adjective and noun condition contained lexical root+(e)n combinations (e.g., *verheilen* 'to heal' with *heilen* 'to heal' as an existing German verb) as well as non-lexical ones (e.g., *vereiteln* 'to foil' with the non-existing substring **eiteln*). Thus, items within one subset did not necessarily have a common internal morphological structure making a coherent interpretation of the results difficult.

Finally, the assumption of morphological structure and lexicality being independent parameters is not straightforward as the internal structure of a *ver*-prefixed verb (right-branching vs. flat) may depend on the lexicality of its substrings (root and root+(e)n). If this is the case, *ver*-prefixed verbs with a lexical root+(e)n combination should have a right-branching structure, while verbs with non-lexical root+(e)n have a flat structure.

3. Aim of the present study and research questions

The present study investigates in how far the processing of polymorphemic German verbs prefixed with *ver-* is influenced by their internal morphological structure. In the previous section, we argued that there are some flaws in the material used by Schirmeier et al. (2004). This is why we aimed at controlling our item sets even more rigorously. Accordingly, we refined the classification system and postulated a fifth subgroup for items with an ambigous root, which may be either derived from a noun or from a verb (cf. 1.2.). Secondly, we only used items with non-lexical root+(e)n combinations in the noun and adjective subset so that, within a subset, all items were consistent with respect to the lexicality of root+(e)n.

Our experiment is designed to test whether the processing of *ver*-prefixed verbs is influenced by their root type and their internal morphological structure. The overall question is whether *ver*-prefixed verbs are represented and processed holistically or in a decomposed form and whether this depends on the specific linguistic properties of the verb.

4. Empirical investigation

4.1. Methods

4.1.1 Participants

62 students (58 women, 4 men, mean age 23.6 yrs) at the University of Potsdam (Germany) participated in the experiment. They are all native speakers of German, right-handed and have normal or correct-to-normal-vision and no reported reading disorder. For participation, they either received course credits or were paid 6 Euros.

4.1.2 Materials

134 German verbs prefixed with '*ver-*' served as target words. They are listed in the appendix. The prefixed verbs were derived from either an adjective (*verblassen* 'to fade' / $blass_{\mathrm{Adj}}$ 'pale'), a noun (*verschlüsseln* 'to encode' / $Schlüssel_{\mathrm{N}}$ 'key'), a verb (*vermischen* 'to mix' / $mischen_{\mathrm{V}}$ 'to

mix'), or a bound morpheme (*verletzen* 'to hurt' / **letz(en)*). For a fifth group of items, the root could not be unambiguously identified and was either a noun or a verb (*verlieben* to fall in love / *Liebe*$_{N}$ love/ *lieben*$_{V}$ to love). All *ver*-verbs were taken from the CELEX database (Baayen et al., 1995), and subsets were matched for full form frequency, root frequency, word length, and number of orthographic neighbours. Prior to the experiment, 60 native speakers of German had classified all verbs as being semantically transparent.[6]

To counterbalance for yes and no responses in the lexical decision task, we invented 134 non-existing but morphologically complex verbs. They were matched in pairs with the targets words according to root type, root frequency, and word length. 25 simple nouns, 25 simple verbs, and 25 simple adjectives, as well as 75 simple non-words served as monomorphemic fillers. Thus, the material contained 418 items which were either morphologically complex (n=268) or simple (n=150) with an equal number (n=209) of existing words and non-words.

Each target item was associated with four different primes, i.e., a related and an unrelated root prime and a related and an unrelated root+(e)n prime. Root primes were free standing monomorphemic adjectives (BLASS) and nouns (SCHLÜSSEL, LIEBE) (for the subsets of adjective, noun, and noun/verb) as well as the monomorphemic familiar imperative (MISCH) for the verb subset and a nonlexical but root-like element (LETZ) for the bound root subset. For the root+(e)n primes, the suffix -*(e)n* was added to the root, resulting in infinitival verbs (MISCHEN, LIEBEN) for the subsets of verb and noun/verb and leading to infinitival-like but nonlexical combinations for the subsets of adjective, noun, and bound root (BLASSEN, SCHLÜSSELN, LETZEN). All prime words were used twice, once in the related and once in the unrelated condition. To keep the priming procedure constant throughout the experiment, polymorphemic fillers were also asscociated with a related and an unrelated root prime and a related and an unrelated root+(e)n prime, respectively. For the monomorphemic words (e.g., *Apfel* 'apple') and non-words (e.g., 'Upfel') we used identity (APFEL/UPFEL) or unrelated (HITZE/PITZE) primes.

4.1.3 Procedure

We created four lists, each containing all items in the same order. Targets and fillers appeared only once per list, and all four priming conditions (related root, related root+(e)n, unrelated root, unrelated root+(e)n) were equally represented in each list. Each prime appeared in only one list so that across lists each target was preceded by a different prime. Thus, all participants were confronted with all items but in one priming condition only.

The experiment was run on a Maxdata notebook using UDAP 3.34 (Universal Data Acquisition Program, Zierdt 1998-2007). Items and primes were presented with black letters (Arial 24) in the centre of a white screen. In the masked priming paradigm (cf. Forster and Davis 1984), each trial consisted of the following sequence: A 450 ms fixation cross (+) was followed by a blank screen (500ms). A forward masking pattern (####), matched in length to each prime word, appeared for 500 ms and was followed by the prime which was presented for 66ms. The prime immediately changed into the target string (word or non-word), which remained on the screen until the participant responded. Primes were presented in upper case and targets in lower case.[7]

Participants were instructed to respond as rapidly and accurately as possible whether the target string was a German word or not. Participants made the lexical decision by pressing the left key of a computer mouse for words ('yes') and the right key for non-words ('no'). Response latencies as well as accuracy of response were measured. Participants were not informed about the presence of prime-words and no reaction time or accuracy feedback was given. The experiment was subdivided into 4 blocks with breaks in between. For each participant, the experiment lasted about 40 minutes.

4.2. Results

8308 responses were recorded for the target items. Data from three participants were excluded from the analyses because their overall response accuracy was below 80%. Nine targets (n=4 from the adjective subset, n=3 from the noun subset, n=1 form the noun/verb subset, n=1 from the bound morpheme subset)[8] were excluded from the analyses as less than 50% of the participants had identified them as an existing German word. In addition, we removed from our item set three items which had been classified incorrectly with respect to the part-of-speech of their root.[9]

The overall accuracy for the remaining targets was 92% (range 58-100%), and did not differ significantly between the subsets. However, it should be noted that eight of the nine items that we did not analyse due to enhanced error rates contain a non-lexical root+(e)n combination. We will come back to this observation in the discussion section.

To analyze response latencies and priming effects, we only used correct responses with latencies differing not more than 2 standard deviations (SD) from the mean reaction time of the group. Thus, 6396 RTs (i.e., 90% of analyzable and 97% of correct responses) went into the RT analysis, ranging from 262-1541 ms. Figure 1 shows the overall response latencies for the different subsets of *ver*-verbs collapsed over the four priming conditions. Figure 2 depicts the priming effects measured for root and root+(e)n priming, respectively. Priming effects were calculated by subtracting the mean response latency in related priming conditions from the mean latency obtained for unrelated primes.

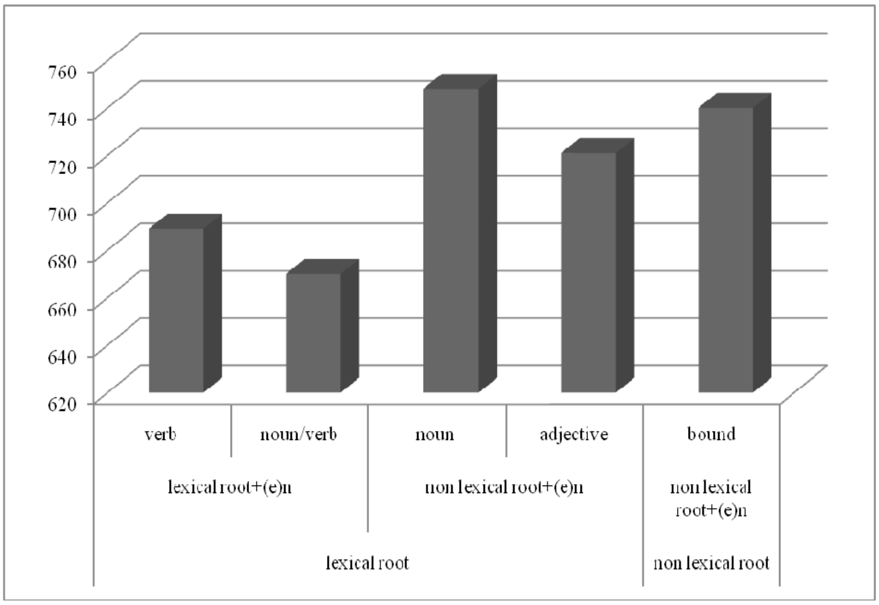

Figure 1. Response latencies (in ms) for different subsets of *ver*-prefixed verbs collapsed over all priming conditions.

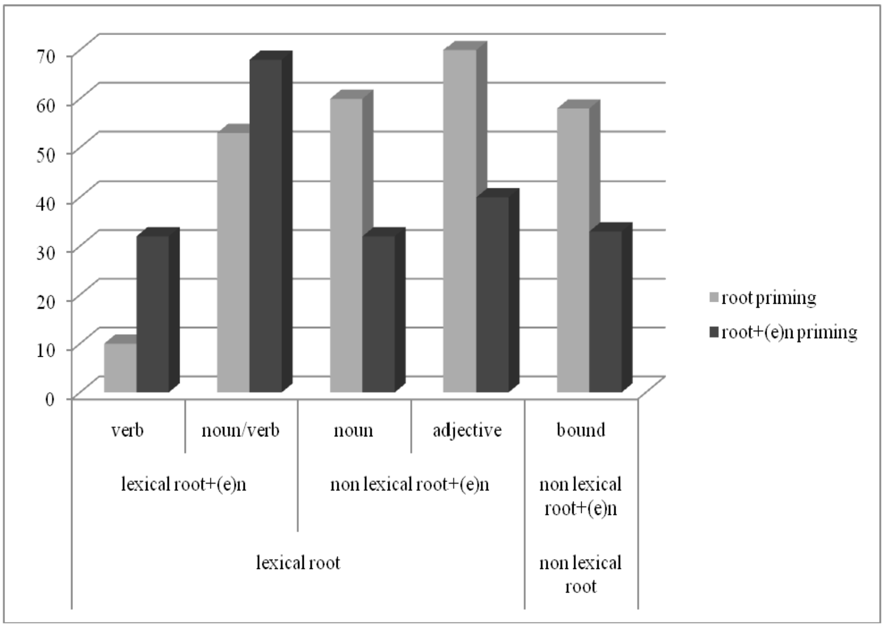

Figure 2. Priming effects (in ms) for different subsets of *ver*-prefixed verbs measured for root priming and root+(e)n priming.

We performed a 5 x 2 x 2 analysis of variance (ANOVA) by participants (F_1) and by items (F_2) with *root type* (verb vs. noun/verb vs. noun vs. adjective vs. bound morpheme), *prime type* (root vs. root+(e)n), and *prime relation* (related vs. unrelated) as independent factors. Both analyses showed a main effect of prime relation (F_1 (1,58) = 63.45, $p < .001$; F_2 (1,117) = 56.98, $p < .001$) indicating that targets were responded to faster after related than after unrelated primes (686 ms vs. 734 ms). In addition, there was a root type effect (F_1 (4,212) = 32.33, $p < .001$; F_2 (4,117) = 3.59, $p < .01$). We did not find a main effect for prime type (F_1 (1,58) < 1; F_2 (1,117) < 1) and no interactions. Thus, root+(e)n priming does not seem to be more effective than root priming (or vice versa), and there is no evidence that the effectiveness of a specific prime type depends on the root type of the items to be primed.

Pairwise comparisons (Bonferroni correction for multiple comparisons applied, all $p < .05$) revealed that both the verb and the noun/verb subset differed significantly from the adjective, noun, and bound morpheme subset. Neither the verb and noun/verb subset nor the adjective, noun, and bound morpheme subsets differed significantly.

The observation that response latencies were significantly shorter for items derived from a verb or a noun/verb than for items derived from an adjective, a noun or a bound morpheme led to a second ANOVA where we replaced *root type* by *morphological structure*. This factor merged the verb and noun/verb items into a new subset “right-branching structure” while the adjective and noun items formed the “flat structure” group. As items with a bound morpheme are not decomposable into lexical units they constituted a third subset. We hypothesized that the root type effect observed would now be reflected in differences between groups differing in terms of morphological structure. Furthermore, we expected that for right-branching items root+(e)n priming is more effective than root priming, while the reverse pattern should be found for items with a flat structure.

We again ran analyses by participants (F_1) and by items (F_2), now with *morphological structure*, *prime type*, and *prime relation* as independent factors.[10] Both analyses showed main effects of morphological structure (F_1 $(2,116) = 48.21$, $p < .001$; F_2 $(2,121) = 5.69$, $p < .01$) and prime relation (F_1 $(1,58) = 65.02$, $p < .001$; F_2 $(1,121) = 47.66$, $p < .001$) but no main effect of prime type (F_1 $(1,58) < 1$; F_2 $(1,121) < 1$). There were no interactions between the three factors. In particular, there was no interaction of morphological structure and prime type (F_1 $(2,116) < 1$; F_2 $(2,121) < 1$) and no interaction of morphological structure, prime type, and prime relation (F_1 $(2,101) = 1.51$, $p = .23$; F_2 $(2,121) = 1.75$, $p = .18$). Pairwise comparisons showed that response latencies were significantly shorter ($p < .001$, Bonferroni correction applied) for items with a right-branching structure than for all other items. Items with a flat structure and items which are not decomposable into lexical units did not differ significantly.

4.3. Discussion

We analyzed response latencies, and morphological priming effects in a visual lexical decision task for different subsets of German *ver*-prefixed verbs. Response latencies differed significantly between the root type subsets. Shorter response latencies were obtained for the verb and noun/verb subset than for the noun, adjective, and bound root subset. Based on these findings the following latency hierarchy depending on the root type emerges (with ‘<’ meaning ‘shorter response latency than’): noun/verb =verb < noun = adjective = bound morpheme. In terms of morphological structure, the hierarchy is right-branching structure < flat structure = not decomposable, respectively. Thus, response latencies were influenced by the lexicality of the root+(e)n combination, with shorter reaction times for lexical than for non-lexical substrings. In contrast, the lexicality of the root did not modulate response latencies, as items with a bound morpheme were recognized equally fast as items derived from a noun or adjective.

Although the accuracy data did not reveal any differences between the subsets, it is worth noticing that for eight of the nine targets which were excluded from the main analyses due to error rates exceeding 50% the combination of root+(e)n was non-lexical. This might be regarded as additional evidence that the recognition of items with non-lexical root+(e)n combinations is more difficult (i.e., slower and more error-prone) than for items with root+(e)n corresponding to an existing verb.

Priming effects, i.e., shorter response latencies following related primes, occurred for both root and root+(e)n priming. This implies that the presentation of a morphological substring, even when it is masked and presented only for a very short time, facilitates the processing of a subsequently presented full form. Our hypothesis that items with a right-branching structure are primed more effectively by a root+(e)n combination than by a pure root, while the opposite effect should be found for flatly-structured items, was not confirmed. Although the overall priming pattern is consistent with our prediction – for flat structures root priming (63 ms) is more effective than root+en priming (35 ms) and for right-branching-structures root+en priming (50 ms) is more effective than root priming (32 ms, cf. Figure 2) – these differences did not turn out to be statistically significant.

Taken together, our results suggest that *ver*-prefixed verbs are represented and processed in a decomposed structure. Morphological priming with root as well as root+(e)n substrings was effective, indicating that the constituent morphemes of the full form correspond to units which are processed during visual word recognition. This is even true for *ver*-verbs derived from a bound morpheme, although neither root nor root+(e)n correspond to a lexical entry in these items.

However, there is some evidence that morphological decomposition does not apply to all *ver*-prefixed verbs in the same way. Shorter response latencies were observed for items with lexical root+(e)n combinations than for items where root+(e)n is not lexical. Thus, we suggest that lexical and non-lexical root+(e)n combinations are processed differently. While the prefix *ver-* is always stripped from the root, this might not be the case for the suffix *-(e)n*. It is reasonable to assume that the suffix is stripped from the root when root+(e)n does not correspond to a lexical entry. In this case, the *ver*-prefixed verbs have a flat structure [ver+root+(e)n] which is composed by circumfixing the root with *ver–* and *–en*. In contrast, the suffix *–en* stays attached to the root when root+(e)n corresponds to a lexical entry, i.e., a verbal infinitive. In this case, the full form's structure is right-branching [ver+[root+(e)n]] and the full form is derived by prefixation. The differences in the response latencies might thus either reflect the different word formation types (prefixation vs. circumfixation) which lead to the morphologically complex full form. Alternatively, it might take longer to compose a full form from three than from two constituents, leading to an advantage for prefixed, right-branching verbs.

While response latencies reflect the flat- vs. right-branching-structure distinction for different subgroups of *ver*-prefixed verbs, the evidence from the priming effects is less convincing. We could not find a statistically significant interaction between prime type (root vs. root+en) and morphological structure (flat vs. right-branching). Still, the effectiveness of root and root+en priming showed a somewhat opposite pattern for flat and right-branching structures which mirrors the latency results.

5. General Discussion and Conclusion

The aim of our study was to investigate in how far the processing of German verbs prefixed with *ver-* is influenced by their internal morphological structure. We showed that despite their homogeneous surface structure of [ver+root+(e)n], *ver*-verbs differ considerably regarding the root type, the lexicality of the root, and the lexicality of the root+(e)n combination. Using a lexical decision task in combination with masked morphological priming, we could show that *ver*-prefixed verbs undergo morphological decomposition during visual word recognition (cf. Taft and Forster 1975 and subsequent studies). Additionally, our data show that morphological decomposition is sensitive to the lexicality of the root+(e)n substring. While *ver*-verbs containing a lexical root+(e)n combination are decomposed into a right-branching [ver+[root+(e)n]] structure, *ver*-verbs with non-lexical root+(e)n combinations are decomposed flatly into [ver+root+(e)n]. Thus, for some *ver*-verbs both prefix and suffix are processed independently from the root. For other verbs, only the prefix is stripped from the root and the suffix remains attached to it.

This observation is not in line with Taft and Forster's (1975) proposal that morphological decomposition is mandatory and that all affixes are stripped from the root during word recognition. Instead, our results may confirm the existence of dual routes for the processing of polymorphemic words (e.g., Caramazza et al. 1988, Pinker and Prince 1994, Baayen and

Schreuder 1999, Clahsen et al. 2003). Existing studies found that various psycholinguistic parameters such as frequency, semantic transparency, and regularity have influence on whether a morphologically complex word is processed holistically or via its constituent morphemes (Bertram et al. 2000, Baayen et al. 2003). Our experiment as well as the study of Schirmeier et al. (2004) show that the processing of complex words is also sensitive to the word's internal morphological structure. In the case of *ver*-verbs, the lexicality of a specific substring (i.e., the combination of root+(e)n) is crucial to whether the suffix is processed separately from the root or not. In contrast to Schirmeier et al. (2004), we therefore do not assume that a right-branching structure is the default for Geman *ver*-prefixed verbs but argue for dual route processing. Although the prefix *ver-* is always separated from the root, either the suffix *-(e)n* may be stripped from the root (for non-lexical root+(e)n combinations in *ver*-verbs derived from nouns, adjectives, and bound morphemes) or root+(e)n may be processed together (in the case of lexical root+(e)n combinations in *ver*-verbs derived from verbs and noun/verbs).

However, it must be noted that, for suffixed words, Clahsen et al. (2003) observed an effect of both root priming and full form frequency. They argue that derived words are represented as full forms in the mental lexicon, but that they are linked to the underived stem form. Our study confirms the effect of root(+en) priming, and we argue that this is evidence for morphological decomposition. An alternative interpretation would be that the priming effects observed constitute evidence for a link between a holistic representation of a prefixed verb and its underived stem form (either root or root+(e)n).

Finally, the results of our experiment can also shed some light on how to construe *ver*-prefixed verbs via prefixation and/or circumfixation. If one assumes that all these verbs are derived by prefixation, some of the complex verbs (e.g., *verschlüsseln* and *verblassen*) violate the *Righthand Head Rule* (Williams 1981, cf. section 1.2.). One approach to reconcile the *ver*-verbs with the RHR was to assume a virtually existing verb matching the root+(e)n combination, which serves as an intermediate form. However, our study showed that there are considerable differences between right-branching *ver*-verbs containing a lexical root+(e)n combination and flatly-structured *ver*-verbs with a non-lexical (or only virtually existing) combination of root+(e)n. Thus, we do not have experimental evidence that such an intermediate form is mentally represented. An alternative explanation was that at least *ver*-verbs with non-lexical root+(e)n combinations are derived by circumfixation. It was unclear, though, whether circumfixation applies to all *ver*-verbs or whether some verbs (those with lexical root+(e)n combinations) are prefixed while others are circumfixed. The differences between right-branching and flatly-structured items observed in our empirical study support an analysis that German *ver*-verbs are indeed construed via two different types of word formation, i.e., prefixation for right-branching full forms and circumfixation for full forms with a flat structure.

Appendix

The appendix shows targets and primes used in the experiment. Targets were assigned to one of five subsets according to their root (verb, noun, ambiguous for verb or noun, adjective, and bound morpheme). Primes were either a related or an unrelated root or root+(e)n combination.
* These items were excluded from the statistical analyses as less than 50% of the participants had identified them as an existing German word.
** These items were were excluded from the statistical analyses as their root was not correctly classified.

VERB (n = 30)
verbeugen BEUG(EN) MISCH(EN); **verbiegen** BIEG(EN) RÜHR(EN); **verblühen** BLÜH(EN) DREH(EN); **verbrennen** BRENN(EN) SPRITZ(EN); **verdrehen** DREH(EN) BLÜH(EN); **vergießen** GIESS(EN) STOPF(EN); **verglühen** GLÜH(EN) SENK(EN); **verjagen** JAG(EN) WEH(EN); **verkriechen** KRIECH(EN) SCHÄTZ(EN); **verleihen** LEIH(EN) REIB(EN); **verleugnen** LEUGNE(N) SCHÜTT(EN); **vermischen** MISCH(EN) BEUG(EN); **verneigen** NEIG(EN) STRÖM(EN); **verreiben**** REIB(EN) LEIH(EN); **verrühren** RÜHR(EN) BIEG(EN); **verschätzen** SCHÄTZ(EN) KRIECH(EN); **verschenken** SCHENK(EN) WARN(EN); **verschicken** SCHICK(EN) TREIB(EN); **verschütten** SCHÜTT(EN) LEUGNE(N); **versenken** SENK(EN) GLÜH(EN); **verspritzen**** SPRITZ(EN) BRENN(EN); **verspüren** SPÜR(EN) TROCKNE(N); **verstopfen** STOPF(EN) GIESS(EN); **verströmen** STRÖM(EN) NEIG(EN); **vertrauen** TRAU(EN) WISCH(EN); **vertreiben** TREIB(EN) SCHICK(EN); **vertrocknen** TROCKNE(N) SPÜR(EN); **verwarnen** WARN(EN) SCHENK(EN); **verwehen** WEH(EN) JAG(EN); **verwischen** WISCH(EN) TRAU(EN)

NOUN (n = 30)
verarzten ARZT(EN) FEIND(EN); **verdoppeln** DOPPEL(N) WURZEL(N); **verebben*** EBBE(N) SEUCHE(N); **vereisen** EIS(EN) GAS(EN); **verfeinden** FEIND(EN) ARZT(EN); **vergasen** GAS(EN) EIS(EN); **vergiften** GIFT(EN) ZOLL(EN); **vergittern** GITTER(N) SCHLEIER(N); **verglasen** GLAS(EN) ZINS(EN); **vergolden** GOLD(EN) HOLZ(EN); **verholzen*** HOLZ(EN)

GOLD(EN); **verkörpern** KÖRPER(N) SIEGEL(N); **verkraften** KRAFT(EN) SCHLÜSSEL(N); **vermarkten** MARKT(EN) STEIN(EN); **vernebeln** NEBEL(N) TEUFEL(N); **verpflichten** PFLICHT(EN) SCHIFF(EN); **verramschen** RAMSCH(EN) SCHLAMM(EN); **verriegeln** RIEGEL(N) WUNDE(N); **versanden*** SAND(EN) TEIL(EN); **verschiffen** SCHIFF(EN) PFLICHT(EN); **verschlammen** SCHLAMM(EN) RAMSCH(EN); **verschleiern** SCHLEIER(N) GITTER(N); **verschlüsseln** SCHLÜSSEL(N) KRAFT(EN); **verseuchen** SEUCHE(N) EBBE(N); **versiegeln** SIEGEL(N) KÖRPER(N); **versteinern**** STEIN(EN) MARKT(EN); **verteufeln** TEUFEL(N) NEBEL(N); **verwunden** WUNDE(N) RIEGEL(N); **verzinsen** ZINS(EN) GLAS(EN); **verzollen** ZOLL(EN) GIFT(EN)

NOUN/ VERB (n = 30)

verärgern ÄRGER(N) KLAGE(N); **verbluten** BLUT(EN) SALZ(EN); **verehren** EHRE(N) HEXE(N); **verfetten** FETT(EN) KOCH(EN); **verfilmen** FILM(EN) PLAN(EN); **verfluchen** FLUCH(EN) SPOTT(EN); **verhexen** HEXE(N) EHRE(N); **verhungern** HUNGER(N) MAUER(N); **verklagen** KLAGE(N) ÄRGER(N); **verkleiden** KLEID(EN) STAUB(EN); **verkochen** KOCH(EN) FETT(EN); **verlieben** LIEBE(N) SCHMERZ(EN); **verlosen** LOS(EN) SCHULD(EN); **vermauern** MAUER(N) HUNGER(N); **verpflanzen** PFLANZE(N) STEUER(N); **verplanen** PLAN(EN) FILM(EN); **verreisen** REISE(N) ZWEIFEL(N); **versalzen** SALZ(EN) BLUT(EN); **verschmerzen** SCHMERZ(EN) LIEBE(N); **verschmutzen** SCHMUTZ(EN) SCHRECK(EN); **verschrecken** SCHRECK(EN) SCHMUTZ(EN); **verschulden** SCHULD(EN) LOS(EN); **verspeisen** SPEISE(N) ZAUBER(N); **verspotten** SPOTT(EN) FLUCH(EN); **verstauben** STAUB(EN) KLEID(EN); **versteuern** STEUER(N) PFLANZE(N); **verteilen** TEIL(EN) SAND(EN); **verwurzeln** WURZEL(N) DOPPEL(N); **verzaubern*** ZAUBER(N) SPEISE(N); **verzweifeln** ZWEIFEL(N) REISE(N)

ADJECTIVE (n = 24)

verarmen ARM(EN) ENG(EN); **verbittern** BITTER(N) FINSTER(N); **verblassen** BLASS(EN) FREMD(EN); **verblöden** BLÖD(EN) DICK(EN); **verdeutschen*** DEUTSCH(EN) EINZEL(N); **verdichten** DICHT(EN) SPÄT(EN); **verdicken** DICK(EN) BLÖD(EN); **verdummen** DUMM(EN) FLACH(EN); **verdünnen** DÜNN(EN) EDEL(N); **veredeln** EDEL(N) DÜNN(EN); **vereinzeln** EINZEL(N) DEUTSCH(EN); **verengen** ENG(EN) ARM(EN); **verfinstern** FINSTER(N) BITTER(N); **verflachen*** FLACH(EN) DUMM(EN); **verfremden** FREMD(EN) BLASS(EN); **vergreisen** GREIS(EN) STEIF(EN); **verknappen*** KNAPP(EN) TEUER(N); **vermiesen** MIES(EN) TIEF(EN); **verspäten** SPÄT(EN) DICHT(EN); **versteifen** STEIF(EN) GREIS(EN); **verstummen** STUMM(EN) WIRR(EN); **verteuern** TEUER(N) KNAPP(EN); **vertiefen*** TIEF(EN) MIES(EN); **verwirren** WIRR(EN) STUMM(EN)

BOUND MORPHEME (n= 20)

verdauen DAU(EN) LIER(EN); **vergessen** GESS(EN) WÖHN(EN); **vergeuden** GEUD(EN) ZICHT(EN); **vergnügen** GNÜG(EN) RING(EN); **vergraulen** GRAUL(EN) KORKS(EN); **verheddern** HEDDER(N) QUICK(EN); **verkorksen** KORKS(EN) GRAUL(EN); **verletzen** LETZ(EN) RENK(EN); **verleumden**

LEUMD(EN) SCHLEISS(EN); **verlieren** LIER(EN) DAU(EN); **vermasseln** MASSEL(N) SCHWEND(EN); **verprassen** PRASS(EN) SEHR(EN); **verquicken** QUICK(EN) HEDDER(N); **verrenken** RENK(EN) LETZ(EN); **verringern** RINGER(N) GNÜG(EN); **verschleißen** SCHLEISS(EN) LEUMD(EN); **verschwenden** SCHWEND(EN) MASSEL(N); **versehren*** SEHR(EN) PRASS(EN); **verwöhnen** WÖHN(EN) GESS(EN); **verzichten** ZICHT(EN) GEUD(EN)

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Notes

1. Whether the suffix is *-en* or *-n* depends on the phonotactic features of the root.
2. The latter root type can be motivated diachronically (e.g., *-gess-* stems from Old Icelandic *geta* ‘to get’, Drosdowski 1989), but bears no meaning in present-day German and is no longer an independent morpheme.
3. Note that although *schlüsseln* does not correspond to an existing German verb; it may occur as a free-standing noun as in “mit den Schlüsseln” (with the keys). However, Schirmeier et al. (2004) argue that within a *ver*-prefixed verb the suffix *-(e)n* must be verbal and cannot be interpreted as a plural morpheme. Therefore, in the case of *verschlüsseln* the substring *schlüsseln* is indeed non-lexical.
4. Some verbs may have either perfective or modal meaning, e.g., *verlaufen* means both ‘to flow’ and ‘to get lost’, the latter being a reflexive verb.
5. But see note 3: Most root+(e)n combinations correspond to a freestanding German word; however, they cannot be licensed as a word within the *ver*-prefixed verb.
6. Following Derwing (1976) and Schirmeier et al. (2004), 60 participants who did not take part in the main experiment had decided for 446 *ver*-prefixed verbs whether the full form (*verblassen*) contains the meaning of its root (*blass*). Results were obtained on a rating scale (0-4), “0” meaning “definitely not” and “4” meaning “definitely yes”. Items with a mean score of 3 and higher were classified as semantically transparent.
7. According to the orthographic conventions of German, the simple nouns used as fillers were presented with an initial capital letter.

8. These targets are *verdeutschen, verflachen*, *verknappen*, *vertiefen*, *verzaubern*, *verebben*, *verholzen*, *versanden*, and *versehren* (cf. appendix). Crucially, the matching condition of the five subsets was held constant with respect to all critical psycholinguistic parameters after the items had been removed.
9. The item *versteinern* 'to petrify' was originally classified as being derived from a noun (*Stein* 'stone'), but might also be derived from an adjective (*steinern* 'made of stone'). The items *verreiben* 'to levigate' and *verspritzen* 'to splash' were originally classified as being derived from a verb although the root is ambiguous as noun and verb.
10. The items *verreiben* and *verspritzen* were included in this analysis (belonging to the right-branching subset) and there were 6396 analyzable reactions in total.

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