Paradigms in the mental lexicon: Evidence from German

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ABSTRACT

Previous research showed that the mental lexicon is organized morphologically, but the evidence was limited to words that differ only in subphonemic detail.

We investigated whether word forms that are related through morphology but have a different stem vowel affect each other's processing. We focused on two issues in two auditory lexical decision experiments. The first is whether the number of morphologically related word forms with the same stem vowel matters. The second is whether the source of similarity matters.

Word recognition experiments have shown that word forms that are phonologically embedded and related through inflection speed up each other's recognition, suggesting the word forms are represented within one unit in the mental lexicon. Research has further shown that words that are related through derivation, but that are phonologically different, are affected in a different way than words that are related through inflection. We conducted two experiments to further investigate this.

We used three subtypes of one inflectional class of German nouns, which allowed us to study different word forms with a phonological difference, while keeping the morphological relations among the word forms constant. All of these nouns have a plural form that ends in a -ə. They differ in the distribution of front and back vowels in the singular, plural and diminutive. This allows us to investigate the question whether word forms with different phonemes are processed differently with regard to (a) the number of word forms that share a vowel, and (b) the source of the similarity among the word forms; is the processing among word forms related through inflection different from the processing of word forms that are related through derivation?

We found that nonces that are based on word forms with a fronted vowel are mistaken for words when they resemble words in the word family, but not when they are unrelated to words in the word family. This shows that morphological effects in word auditory recognition studies are also found when the word forms differ in a full phoneme. We argue that this can be captured with a network representation, instantiated as a frame.

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Keywords: Mental lexicon, word family, German inflectional classes, lexical decision, frame representation

1 INTRODUCTION

The repository of words in memory—the mental lexicon—is organized in intricate ways. Different degrees of similarities, and different dimensions of similarity affect the recognition of words to different degrees, and these differences allow us to draw conclusions about the structure of word forms in the mental lexicon (McQueen and Cutler [1998] [McQueen et al. [1995] [McQueen [2007]]. In this paper we explore the relationships among inflected words (singulars and plurals), and derived words (diminutives) in German. The umlaut-system of German, in which back vowels are fronted in particular morphological contexts, allows us to investigate morphological relations among word forms that cannot be reduced to phonetic similarity.

Words that sound similar facilitate each other’s recognition. Words that share phonological material are considered in parallel for lexical access in all models of spoken word recognition (Weber and Scharenborg [2012]). The Dutch words kapitaal 'capital’ and kapitein ‘captain’, which share sounds but not meaning, are both considered after hearing the first two syllables (Zwitserlood [1989]) and the word bone is activated after hearing trombone (Isel and Bacri [1999]).

A similar facilitation has been found for words that share meaning. In a lexical decision experiment Marslen-Wilson and Zwitserlood [1989] found that the prime honing 'honey’ speeded up the recognition of the semantically related word bij ‘bee’.

Recent models of word recognition treat words that are similar because of their morphological relatedness in the same way as words that are only phonologically, but not morphologically similar (Weber and Scharenborg [2012]). There is, however, evidence from the literature that morphology should be more strongly incorporated in such models. The facilitatory effects among phonologically and semantically similar words on word recognition come together in morphologically related words. The words Boot ’boat’ and Boote ’boats’, for example, affect each other’s recognition more strongly than neighbors that are only phonologically related. For example, the recognition of car is facilitated by its plural cars, but less by the unrelated card (Stanners et al. [1979]), even though cars and card both differ in one phoneme from car.

Diving deeper into the relationships among morphologically related words in German, Schriefers et al. [1992] found in two experiments that word forms that are members of the same word family often influence each other’s response latencies. In a first experiment they investigated relationships among inflected words, and in a second experiment they investigated the relationships among inflected and derived words.

In the first experiment they investigated four types of inflection in adjectives; adjectives with the nominative suffix -e (klein-[ə] 'small NOM, F/N/M’; the dative suffix -em of the strong declension of masculine and neuter adjectives (klein-[əm] 'small DAT, M/N’); adjectives ending in the suffix -es, which indicates nominative and accusative in the strong declension (klein-[əs] 'small NOM/ACC, N’); adjectives without suffix. They found asymmetries between the suffixes. Uninflected adjectives facilitated the recognition of all inflected adjectives. Adjectives inflected with [ə] facilitated the recognition of uninflected adjectives as well as inflected adjectives. Adjectives inflected with [əm] only facilitated recognition of itself and adjectives inflected with [ə], and, finally, adjectives inflected with [əs] only facilitated recognition of itself and adjectives inflected with [əm].

1 A model that might incorporate such information is proposed by Gaskell and Marslen-Wilson [1997], whose distributed model of speech perception incorporates phonological and semantic information. However, it is not entirely clear how this should be implemented, and it is beyond the scope of this paper to develop a model of speech recognition.

This is a provisional file, not the final typeset article
In a second experiment [Schriefers et al. (1992)] looked at the response latencies between inflected and derived words. They used the derivational suffixes -lich, to create derived adjectives or adverbs (e.g. kleinlich ‘petty’), and -heit (e.g. Kleinheit ‘smallness’), to create abstract nouns. Additionally, they used uninflected adjectives and inflected adjectives ending in -es. It turned out that uninflected adjectives prime all other items; adjectives ending in -es prime adjectives but not derived items; derived -heit items prime uninflected adjectives and themselves, but not other items; derived -lich adjectives prime themselves, but not other items. It appears that there is an asymmetry among the derived items: Derived -heit items prime uninflected adjectives, but derived -lich items do not. [Schriefers et al. (1992)] speculate that this difference among derived forms is a result of the stem vowel change that accompanies most -lich items, called umlaut. For example, the adjective rot ‘red’, has a fronted vowel when it is derived with -lich: rötlich ‘reddish’. This finding suggests that phonologically similar word forms affect each other in a priming study, but when the word forms are not phonologically similar, if they differ in a vowel as the vowel in rot and the first vowel in rötlich do, they do not facilitate each other’s recognition.

The findings of [Schriefers et al. (1992)] for German were corroborated and extended by [Ernestus and Baayen (2007b)] for Dutch. They observe that words in a paradigm—words that are related through inflection—are effectively neighbors of each other. Inflected words differ from uninflected words in one or more affixes. This fact alone would make them neighbors, and in addition an inflected word is embedded in an uninflected word, which affects its duration [Kemps et al. (2005)]. It has been shown that words that are embedded in longer words, such as ham in hamster, are shorter than when they are standing alone. This difference in length is noticeable to listeners [Davis et al. (2002); Ernestus and Baayen, 2007b; Kemps et al. (2005); Salverda et al. (2003)]. Kemps et al. (2005) showed that participants take longer to decide whether an item is a word when its duration is off: if the string of a singular form [bek] ‘brook’ is given the (shorter) duration of the same string embedded in the plural form [beko] ‘brooks’, it takes longer to recognize as a word than when it is presented with its normal duration. If the string of the singular embedded in the plural [beko] is given the duration of the singular [bek] it is also recognized more slowly than when it has its expected duration.

Since speakers are aware of small phonetic differences, the question arises whether such small differences play a role in word recognition in paradigmatically related words. [Ernestus and Baayen (2007b)] investigated this question for paradigmatically related words in Dutch.

Dutch has final devoicing; the stem-final obstruent in the plural [hunda] ‘hands’ is voiced, whereas its correspondent in the singular [hand] ‘hand’ appears to be voiceless, indicated in IPA by the ring underneath the d. However, there are traces of voicing in the singular that are small and subphonemic, but nevertheless noticeable [Warner et al. (2004)]. The vowel in [hant], in which the final obstruent is devoiced, is slightly longer than it is in comparable words that have no voicing alternation in its paradigm, such as [krant] (Ernestus and Baayen (2003) 2006; 2007a[b]; Warner et al. 2003, 2006, 2004). In words such as krant ‘newspaper sg.’ a completely voiceless stem-final obstruent has a completely voiceless correspondent in the plural [krunta] ‘newspapers.

In a lexical decision experiment [Ernestus and Baayen (2007b)] compared judgements about the lexical status of two groups of nonces that were based on existing Dutch words. The nonces in one group, exemplified by *[krant], had no support from members in its paradigm. There are no allomorphs that contain the string *[krant]. Nonces in the other group, exemplified by *[hand], do have support from other words in the word family. The plural allomorph of the singular [hant] hand ‘hand’ is [hunda] handen ‘hands’. The singular [hant] shows traces of the voicing of the final obstruent in other forms in its word family (Ernestus and Baayen 2003; Warner et al. 2004; Ernestus and Baayen, 2007b 2006). It turned
out that nonces that have no support in the paradigm are rejected faster as words than nonces that do have
support from other members in the word family.

Ernestus and Baayen’s interpretation of the effects is based on the amount of support the nonce word
receives in the word family. Since the effect is cumulative, the representation of a word family can be
interpreted as a list. If a nonce is embedded in many members of the word family, the effect is stronger than
when the nonce is embedded in few or even in no members. However, if a word family is represented as a
list, the findings of asymmetrical priming as reported by Schriefers et al. (1992) are difficult to interpret. In
a list interpretation, the amount of support for a word form in a word family is crucial, not the source of
support for a word form.

The evidence presented from German (Schriefers et al., 1992) and Dutch (Ernestus and Baayen, 2007b)
suggests that word forms in the mental lexicon are organized along morphological lines. The word forms
of the same word family affect each other’s response latencies. However, in all data we have considered so
far the word forms that affected each other were very similar; they only differed in small phonetic detail.
The word forms were either embedded in each other and therefore had only small subphonemic durational
differences in both languages.

This leaves open the question as to the generality of the morphological effect both studies reported.
Would word forms that differ in one phoneme, rather than just in subphonemic detail, also affect each
others recognition? Another question concerns the results from Schriefers et al. (1992), who found that
priming is not equally strong among the members of the word family, which suggest that a word family is
not simply a list. This raises the question as to what is the structure of a word family.

Schriefers et al. (1992) analyze their results within a network model, in which the lexicon is made up of
nodes for words, morphemes, syllables and phonemes. Stems are morpheme nodes to which each word
is connected. Since morphological variants share a stem node they are connected through a shared stem,
but not directly through a shared lexical entry. For example, the stem klein is present in all inflected forms
of the adjective, as well as in the derived forms kleinlich and Kleinheit. The stem rot is not present in the
derived form rötilich. This model, then, explains their results.

Yet, Schriefers et al.‘s network model needs to be modified. Their assumption that stems are stored
separately in the mental lexicon is called into question by two sets of findings. First, there is accumulating
evidence that complex words are stored and processed as wholes. Schreuder and Baayen (1997) found
that reaction times to simplex words are modulated by the frequency of whole complex words, and not
by the summed frequency of their individual morphemes. This is true even in agglutinative languages
(Lehtonen et al., 2007; Moscoso del Prado Martín et al., 2004; Vannest et al., 2002). This shows that
network models are correct in assuming that the mental lexicon is a network of connected nodes; words
that share phonological form and meaning through shared morphology are activated simultaneously. But it
also shows that complex words are stored as wholes.

Another argument against the centrality of stems in the network model comes from instances of paradigm
leveling; members of a paradigm are often adjusted to each other–levelled–in order to make them more
similar. An example of such leveling is found in Dutch. In Dutch [n] is normally not pronounced after
a [a]. The infinitive of lopen ’to walk’ is pronounced [lopa]. Only under very formal circumstances it is
pronounced [lopan] (Booij, 1995). The first person singular present tense is ik loop, pronounced [ik lop],
and often analyzed as the stem form. However, in case an infinitive ends in a sequence [on], as in oefenen
[ufo@n] ’to practice’, the first person singular, present tense is ik oefen [ik uf@n], and not *[ik uf@o] (Koefoed,
1979). Even though this process is correctly described as blocking of [n]-deletion at the end of a verbal
In short, the paradigm-as-list model of Earnestus and Baayen (2007b) is insufficient because paradigms are not lists, and the network model of Schriefers et al. (1992) is insufficient because paradigmatic effects go beyond shared stems. A representation of a paradigm needs to capture the dependencies among its word forms. This, then, raises the question as to how paradigms can be represented.

Frame representations allow us to capture the dependencies effects mentioned above (Barsalou 1992; Gamerschlag et al. 2013; Löbner 2014; Petersen and Osswald 2014). In a frame the properties of a central node are represented as attribute-value structures. Attributes are functions that return a value. We will now analyze inflectional classes of German nouns as sets of (recursive) attribute-values pairs.

We propose to represent the inflectional classes of German nouns (Eisenberg 2004; Köpcke 1988; Thieroff and Vogel 2009) as frames. The central node of each class is the category noun, and its attributes and their values are morphological and phonological properties that define an inflectional class. Providing a full overview of all inflectional classes is beyond the scope of this paper. Instead we provide frame representations of the class of nouns that has a plural that ends in a schwa—these nouns will also be at the heart of our experiments. The frame representations of these nouns are illustrated in figures 1, 2, 3 and 4. Each frame represents one subclass of nouns. The central node—the referential node—is indicated by a double circle, that attributes in small caps and their values in italics.

In addition to providing an argument against the centrality of stems, paradigm leveling also highlights the fact that paradigms have structure and should not be represented as a list. In Dutch paradigm leveling, as we have seen above, plural verbal forms asymmetrically affect the singular forms. Such asymmetrical relations have also been observed for morphological features that make up a paradigm (Blevins 2016; Haspelmath and Sims 2010; Seyfarth et al. 2014). In German nouns, for example, it has been observed that in some inflectional classes there is a dependency between genitive forms and plural forms, but the reverse is not true. If the genitive of a noun ends in [an], for example, the plural does as well: the genitive form of Mensch [mənʃ] ‘human being is des Mensch-en [des mənʃәn] ‘human being-GEN’, and its plural is die Menschen [diː mɛnsən] ‘human being-PL’. A plural ending in [an] does not necessarily imply a genitive in [an]: the plural form die Staaten [diː ʃtaːtən] ‘the state-PL’ has as genitive des Staates [dɛs ʃtaːtəs] ‘the state-GEN’ (Eisenberg 2004; Thieroff and Vogel 2009). Morphological properties sometimes depend on phonological properties (see also Neef 1998). For example, if a plural ends in [a] its singular ends in a closed syllable. This is true for words such as Bart ‘beard’ Bärte ‘beard-PL’, Boot ‘boat’ Boote ‘boot-PL’ and Fest Feste ‘party, celebration-PL’. The reverse, again, is not always true. Singulairs such as Mensch or Staat have a plural that ends in en: Menschen and Staaten.

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Frontiers
The paradigm of the nouns illustrated in figure 1 are masculine, end in a closed syllable, have a genitive that ends in [as], and a plural that ends in [a]. It is exemplified by the word forms [tak] Tag 'day' for the nominative, [tagas] for the genitive and [tago] for the plural. The paradigm of the nouns illustrated in figure 2 are masculine, end in a closed syllable, have a genitive that ends in [as], and a plural that ends in [a] and has a front vowel. It is exemplified by the word forms [bart] Bart 'beard' for the nominative, [bartas] for the genitive and [brot], with a front vowel, for the plural. The paradigm of the nouns illustrated in figure 3 are feminine, end in a closed syllable, have a plural that ends in [a] and has a front vowel. It is exemplified by the word forms [hant] Hand 'hand' for the nominative, and [hando], with a front vowel, for the plural. The paradigm of the nouns illustrated in figure 4 are neuter, end in a closed syllable, have a genitive that ends in [as], and a plural that ends in [a]. It is exemplified by the word forms [bot] Boot 'beard' for the nominative, [botas] for the genitive and [boto] for the plural.

Now that the inflectional classes are represented as frames we can add diminutives. Typological work on diminutives shows that that they are lexically different from their base. In an overview of the typology of meaning of diminutives Jurafsky [1996] finds that, in addition to denoting smallness, diminutives can also denote affection, pejorative meanings or even contempt. This also holds for German diminutives. The word form spelled Bärtchen may refer to a small beard, either to indicate its smallness or to express a measure of contempt. The word form Frauchen, in contrast, can only refer to a woman who owns a pet–usually a dog–irrespective of the size of the woman. The word form Brötchen, as a further example, can only refer to a roll, no matter what its size, and never to a small loaf of bread. As these meanings are partly lexicalized they must be stored in the mental lexicon.

The change in meaning associated with derived forms, as with diminutives, is analyzed as a shift of the referent from one node to another (Andreou 2018; Kawaletz and Plag 2015). This is illustrated in figure 5. The referent of the noun has shifted to the node that contains the value of the attribute HAS-SIZE.

In the figures 1, 2, 3 and 4 a branch with attribute-values for size size was omitted to avoid cluttering the representation. The frames in these figures do include such a branch the crucial difference with the representation of a diminutive as in figure 5 is the referential node, indicated with a double circle. The
To further investigate the role of morphology in word recognition and to test the predictions of our proposed frame representations, we will study the responses latencies in a particular type of German noun in an auditory lexical decision experiment. The nouns of this type are characterized by taking a [ɔ] in the plural, and their representations as frames are given in figures 1, 2, 3, 4 and 5 above. They can be divided into three subgroups (Köpcke, 1988) (Examples are given in table 1.) In one subclass the nouns have a back vowel in the singular and front vowels in the plural and the diminutive; for example, Bart [baʁt] 'beard', Bärte [baʁtə] 'beards' and Bärtchen [baʁtçɔn] 'little beard'. We will refer to this group of nouns as Type 1 referent can be selected dynamically by the speaker or hearer as needed (Kawaletz and Plag, 2015; Andreou, 2018).
nouns (see figure 2 and 3). The nouns in the second subclass of this inflectional class have a back vowel in
the singular and the plural, and a front vowel in the diminutive Boot [bot] 'boat', Boote [bota] 'boats' and
Bötchen, [bøtç@n] 'little boat'. We will refer to this group of nouns as Type 2 nouns (see figure 1 and 4).
The nouns in the third subgroup have a front vowel in all three word forms: Fest [fEst] 'party, celebration',
Feste [festa] 'parties, celebrations' and Festchen [fEstç@n] 'little party, little celebration'. We will refer to
this group of nouns as Type 3 nouns (see figure 1 and 4).

Table 1. The noun types of the inflectional class in our study. V = Vowels, f = front, b = back

| Inflection | Type 1 V | Type 2 V | Type 3 V |
|------------|----------|----------|----------|
| Bart       | bæt| b       | fæst| f       |
| Booët | fæta| f       | fæsta| f       |

This class of nouns allows us to address two questions that have arisen from the research summarized
above. The first question is: Are morphological effects in word recognition limited to word forms that are
embedded in each other, or do they extend to all word forms that are morphologically related; even to word
forms that differ in a vowel? The nouns in in our word families are not always embedded in each other;
they sometimes have a different vowel (for type 1 and type 2). For example the word form [bA5t] is not
embedded in the word form [bE5t@]. The second question is: What is the structure of the representation of a
word family? Since the nouns are not embedded in each other we are able to discern different effects for
different sources of similarities, should there be evidence for an asymmetric structure; (if the source of
similarity of a nonce is an inflected form, is it processed differently than when the source of similarity is a
derived form?) If the word forms in a paradigm are represented together with derived word forms in one
frame, as in figure 5, we also expect that inflected forms are more strongly associated with each other than
derived word forms with inflected word forms. The derived word form has a different referential node than
the inflected word forms.

These nouns form an excellent empirical basis for our investigation. We can create nonces for each type
by changing the backness of a word form. For example, in one experiment we changed the word [bæt] to
the nonce [bøt], in the other experiment we changed the word [bæta] to the nonce [bøta]. These nonces
can show us whether the amount of word forms that are similar to the nonce affects it processing, and
whether the source of the similar form (an inflected form or a derived form) affects it processing.

This brings us to our expectations. The first set of expectation concerns the role of morphology in word
recognition. The evidence provided by Schriefers et al. (1992) and Ernestus and Baayen (2007b) shows that
morphologically related word forms affect each other’s response latencies, but their evidence is limited to
word forms that differ only in subphonemic duration. To see whether the effect is morphological in nature
we will use words that are morphologically related and differ by a phoneme, rather than in subphonemic
duration only. We expect that the recognition of nonces of type 1 (see table 1) above is affected by their
relation to existing word forms that are morphologically related, despite their phonological difference with
an existing word. The more easily a nonce is mistaken for a word, the more mistakes participants will make
in their accuracy and the more their response latencies will be affected.

The second set of expectations relates to the structure of the representations of inflected and derived
words in the mental lexicon. If these are stored in the mental lexicon as the specific frame proposed in
figure 5 in which diminutives have a different referential node than plain nouns, we expect that diminutives exert less influence on singular and plural nouns than singular and plural nouns on each other; singular and plural nouns share a referential node. This difference in referential nodes will affect both the accuracy and the response latencies.

We ran two auditory lexical decision tasks and measured the accuracy and response latency to words and nonces. Our method is slightly different from the one used in Ernestus and Baayen (2007b). We did not tell our participants to accept a nonce if it occurs in a word, but rather we asked them to judge whether an item is a word or not.

2 EXPERIMENT 1

In the first lexical decision test we investigated whether the accuracy and speed with which a nonce with a front vowel, as in the case of type 1 [bre̞t], or type 2 [bot], is judged, and if the accuracy and speed correlate with the amount of such stems in the word family. The nonce [bre̞t] has support from 2 words in the word family and [bot] is supported by only one word form.

2.1 Participants

Fifty-six native monolingual German adults took part in the experiment (these participants did not take part in experiment 2.) All of them were students at the University of Düsseldorf and they were given course credit for their participation. Their mean age was 20 years and 5 months. Forty-six women and 10 men participated; 50 of them were right-handed. One participant holds a university degree in a non-linguistic subject and all other participants reported to have a secondary school diploma that qualifies as entrance for a university as their highest educational degree. All participants had normal hearing and normal or corrected vision, and none of them reported any neurological problems.

2.2 Material

The material consisted of 90 German words (they are listed in the Appendix ??). All material was recorded in a carrier sentence Ich habe X gesagt. ’I said X.’ to ensure that the words have comparable prosodies. The words were excised from the sentences with Praat (Boersma and Weenink, 2018).

We used thirty Type 1 words: Monosyllabic words with a back stem vowel in the singular (e.g. Bart bA5t ’beard’) and a front vowel in the plural (Bärte bE5t@) and the diminutive (Bärtchen bE5tç@n). We created thirty nonces by giving the singular a front vowel (e.g. bE5t). The nonce has the same vowel as two allomorphs in the paradigm of Bart: the plural allomorph and the diminutive allomorph. Apart from the value of the [back] feature nothing in the word was changed in order to preserve its syllable structure.

We further used thirty Type 2 words: Monosyllabic words with a back vowel in the singular (e.g. Boot bøt ’boat’) and the plural (e.g. Boote bøt@) and a front vowel in the diminutive (e.g. Bötchen bøtç@n). We created thirty nonces by giving the singular a front vowel (e.g. bøt). This nonce has the same vowel as the diminutive.

The last group of thirty words were Type 3 words. They were also monosyllabic and had either front vowels in the singular, plural and diminutive stem or a back vowel in the singular. Nonces in this group of items were created by inverting the value of the [back] feature of the singular: if the singular had a front vowel, such as Fest [fEst] ’party’, the nonce was given a back vowel: [fOst]; if the singular had a back vowel, such as Pott [pOt] ’mug’, the nonce was given a front vowel: [prt].
In addition we selected 180 existing monosyllabic words as fillers and 180 nonces based on these fillers. The total amount of items was therefore 540. They are all listed in Appendix 5. As fillers we used monosyllabic nouns with front vowels from the same inflectional class as the words.

To be able to estimate the effect of frequency on our results, but we found no significant differences in frequency among the types of words in our experiments. We provide the details, therefore, in an appendix 5. We also estimated the neighborhood density of the words in our experiment. Here, too, we found no significant differences among the word types and provide the details in an appendix 5.

We created two lists, A and B, to prevent a sequence of a word and a related filler in the experiment. Half of the words were in list A and the other half was in list B. The nonces based on the words in list A were put in list B and the nonces based on the words in list B were put in list A.

2.3 Procedure

The experiment was programmed with PsyScope (Cohen et al., 1993) and was carried out in a quiet room at the University of Düsseldorf. The stimulus material was presented over headphones.

The experiment started with 16 practice trials half of which consisted of words and the other half of pseudo-words that obeyed the phonotactics of German. In the experiment there were 90 words and 90 nonces that we derived from the existing words. In addition we used 180 fillers; again 90 words and 90 pseudo-words.

After this the experimental items were presented in random order for each participant. Each trial started with a silence of 500 ms. followed by a tone of 500 ms. Then, after a silence of 450 ms., an item was presented and the participants had to decide as quickly as possible whether this was a word or not. The participants were instructed to press a key on the keyboard with a green sticker if they thought it was a word and a key with a red sticker if they thought it was not. For half the participants the green button was on the left side of the keyboard and for the other half it was on the right side of the key board. After the participants had made their choice the next trial started after a 2500 ms silence. The experiment lasted about 25 minutes.

2.4 Results

We first consider the accuracy of the participants to words in order to establish that they understood the task; that they correctly accepted words and did not incorrectly reject them. The raw result is summarized in Table 2. The counts in Table 2 show that the words of all types were correctly accepted in more than 93% of the cases.

| Type   | Type 1 (ba5t) | Type 2 (bot) | Type 3 (fEst) |
|--------|---------------|--------------|---------------|
| Correct| 98%           | 93%          | 93%           |

A logistic mixed effects model with accuracy as dependent variable and Type as fixed effect, and random slopes for items and participants shows that the difference in Table 2 is significant, as is illustrated in Table 3.

We expected that nonces of type 1 are more likely to be mistaken for a word, because they resemble two existing word forms in the paradigm. We expected that nonces of type 2 are, in comparison to type 1...
Table 3. Logistic regression analysis of the accuracy of the judgements of the participants to words in in experiment 1

|                          | Estimate | Std. Error | z value | Pr(>|z|) |
|--------------------------|----------|------------|---------|----------|
| (Intercept = type 1)     | 5.19     | 0.46       | 11.35   | 0.00     |
| type2                   | -1.36    | 0.56       | -2.45   | 0.01     |
| type3                   | -1.22    | 0.56       | -2.17   | 0.03     |

Table 4. Proportions of incorrect answers to nonces in Experiment 1

| Type 1 (brøt) | Type 2 (bot) | type 3 (føst) |
|---------------|--------------|---------------|
| Incorrect     | 14%          | 7%            | 9%           |

Table 5. Logistic regression analysis of the accuracy of nonces in experiment 1

|                          | Estimate | Std. Error | z value | Pr(>|z|) |
|--------------------------|----------|------------|---------|----------|
| (Intercept = type 1)     | 2.67     | 0.31       | 8.51    | 0.00     |
| Type 2                   | 1.02     | 0.40       | 2.58    | 0.01     |
| Type 3                   | 0.79     | 0.39       | 2.01    | 0.04     |

The results of the nonces in table 4 show that nonces of type 1 were incorrectly accepted in 14% of the cases, proportionally more than type 2 and type 3 nonces.

Table 6. Linear regression analysis of the log-transformed response latencies of the reaction times to correctly accepted words in experiment 1

|                          | Estimate | Std. Error | df   | t value | Pr(>|t|) |
|--------------------------|----------|------------|------|---------|----------|
| (Intercept = type 1)     | 6.34     | 0.04       | 131.17 | 178.22  | 0.00     |
| Type 2                   | 0.09     | 0.04       | 85.68 | 2.51    | 0.01     |
| Type 3                   | 0.10     | 0.04       | 85.78 | 2.70    | 0.01     |

Nonces of type 1 were more often mistaken for real words than nonces of type 2 or 3. This analysis, then, confirms that nonces of type 1 are more difficult to reject than nonces of type 2 or 3 as expected. In an analysis, which is not shown here, in which type 2 was designated to be the intercept showed that the accuracy of type 2 and 3 nonces is not statistically different.

We will now present the results of a mixed effects model of the log-transformed reaction times of the correctly judged words in experiment 1. The results of a linear mixed effects model with the logarithm of the Reaction time as dependent variable and Type (type 1, type 2, type 3), as fixed factor, and random slopes for Items and Participants is presented in Table 6.
The results of the analysis, presented in table 6, show that words of type 1 are reacted to fastest and that type 2 and type 3 words are reacted to slightly, but significantly slower. In combination with results of the accuracy to words, presented in table 5, it suggests that type 1 words are recognized most accurately and fastest.

We will end the presentation of the results of experiment 1 with a mixed effects model of the reaction times to the incorrectly identified nonces in experiment 1. The participants thought erroneously that these were words and in that case the paradigm may have been activated to influence the reaction times. The number of items over which this analysis was run, was very small, though, as the participants made relatively few mistakes.

The results of a linear mixed effects model with the logarithm of the Reaction time as dependent variable and Type (type 1, type 2, type 3), as fixed factor, and random slopes for Items and Participants is presented in Table 7.

| Estimate | Std. Error | df  | t value | Pr(>|t|) |
|----------|------------|-----|---------|----------|
| (Intercept = Type 1) | 6.67 | 0.05 | 75.00 | 141.58 | 0.00 |
| Type 2 | 0.10 | 0.05 | 56.70 | 1.87 | 0.07 |
| Type 3 | 0.09 | 0.05 | 50.47 | 1.77 | 0.08 |

Even though the reaction times to the incorrectly accepted nonces are not statistically different, there appears to be a tendency to react a bit more slowly to type 2 and type 3 nonces.

We expected that nonces of type 1 were more likely to be mistaken for words, because there is enough support for their assumption within word family of type 1. This expectation turned out to be correct. It was most difficult to correctly reject nonces of type 1 (\[\text{bræt}\]). The difference between making a correct and an incorrect decision is smallest for type 1 nonces and larger for type 2 (\[\text{bot}\]) and 3 nonces (\[\text{fɒst}\]), where there is either support from a derived word form in the word family (type 2) or no support for the nonce (type 3), and therefore more uncertainty on the part of the participants. The data from the reaction time analysis of nonce items are more inconclusive. The participants were so good at rejecting nonce words, that we had few data on which to base our analysis. The tendency of the data, though, is that nonces of type 1 are reacted to more slowly than type 2 and 3 nonces (see table 7).

In short, experiment 1 showed that there is evidence for a role of morphological information in word recognition that goes beyond small subphonemic differences among the parts of words forms in a word family (Ernestus and Baayen, 2007b; Schriefers et al., 1992). This evidence is given by a reduced accuracy for nonces that are supported by many forms in the word family. This support provides the participants with mistaken certainty that they are, in fact, dealing with a word. The analysis of the words provides additional support for this interpretation. Type 1 words are processed fastest (see table 3) and most accurate (see table 6) of the types in our experiment. The singular of type 1 activates the associated inflected and derived word forms and thus makes it more likely for a participant to mistakenly think that a nonce form of type 1 is an existing word.

A different interpretation cannot be ruled out without further evidence. As experiment 1 showed no difference between nonces of type 2 and type 3, it may also be that the source of support caused our results, rather than the amount of support. In this interpretation type 1 nonces are reacted to differently because...
they are similar to an inflected form in the word family, whereas the nonces of type 2 are related to a
derived word and type 3 nonce are not related to any word in the word family.

A second experiment, in which the amount of support for nonces is kept constant will be able to
distinguish these two interpretations.

3 EXPERIMENT 2

The second experiment was a lexical decision experiment as well. Its aim was to investigate whether the
source of similarity among word forms in a word family is relevant. Are nonces processed differently if
they resemble an inflected word form than when they resemble a derived word form? If they are, we expect
differences in accuracy and response latencies among the nonces of different types, correlating with the
source of support for a nonce.

3.1 Participants

Fifty-one native monolingual German adults took part the experiment (these participants did not take
part in experiment 1.) All of them were students at the University of Düsseldorf and they were given
course credit for their participation. Their mean age was 22 years and 5 months. Forty-seven women and 4
men participated. Forty-five participants were right-handed, 6 were left-handed. One participant holds a
university degree in a non-linguistic subject and all other participants reported to have a secondary school
diploma that qualifies as entrance for a university as their highest educational degree. All participants had
normal hearing and normal or corrected vision, and none of them reported any neurological problems.

3.2 Material

We used the bisyllabic plural forms of the German nouns used in experiment 1 and to create nonces we
changed the stem vowel of the plural form.

For the words of type 1—bA5t, bE5t@, bE5tç@n—we created a nonce by changing the front vowel of the
plural word form to back: bA5t@. This nonce is only similar to the the singular word form. Words and
nonces of type 1 nonces are listed in table [15] in the Appendix (section III).

For the words of type 2—bot, bot@, botç@n—we created a nonce form by changing the back vowel of the
plural to front: bøt@. This nonce is only similar to the diminutive word form. Words and nonces of type 2
are listed in table [16] in the Appendix (section III).

For the words of type 3—fEst, fEst@, fEstç@n—we created a nonce form by changing the front vowel of
the plural to back: fOst@ or by changing the back vowel of the plural to front: [pEt@]. Neither of these nonces
are similar to a word form in the word family of the existing words upon which they are based. Words and
nonces of type 3 are listed in table [17] in the Appendix (section III).

In addition we selected as fillers 180 existing bisyllabic plural words from the same inflectional class as
the words, and 180 nonces based on these fillers. The total amount of items was therefore 540. They are all
listed in the Appendix (section III).

3.3 Procedure

The procedure for experiment 2 was identical to experiment 1.
3.4 Results

We first consider the accuracy of the participants. This establishes that the participants understood the task. The data in table 8 show that words of type 1 were recognized best as words, whereas the percentages correct answers to type 2 and 3 words are very similar. These relatively low percentages show that it was relatively difficult for the participants to recognize the words as existing words. The reason might be that the words in experiment 2 are plurals, which were presented to the participants without context. The participants may have expected singulars by default—since singulars are on average more frequent—and, not finding a fitting singular in their mental lexicon, incorrectly rejected it as a word.

Table 8. Proportions of correct answers of words in Experiment 2

| Type | Correct |
|------|---------|
| Type 1 (best) | 1180 (77%) |
| Type 2 (bot) | 1078 (71%) |
| Type 3 (frst) | 1122 (73%) |

A logistic mixed effects model with accuracy as dependent variable and Type as fixed effect, and random slopes for items and participants shows that the difference in table 8 between words of type 1 and 2 is significant. Type 3 words caused more mistakes, but the difference is not significant, as is illustrated in table 9.

Table 9. Logistic regression analysis of the accuracy of the judgements of the participants to words in experiment 2

| Type    | Estimate | Std. Error | z value | Pr(>|z|) |
|---------|----------|------------|---------|----------|
| (Intercept = type 1) | 1.92 | 0.34 | 5.67 | 0.00 |
| Type 2 | -0.70 | 0.23 | -3.00 | 0.00 |
| Type 3 | -0.42 | 0.23 | -1.80 | 0.07 |

Table 10 is an overview of the incorrect acceptance of the nonces in experiment 2. Most mistakes were made in type 1 and type 2 nonces, while the number of mistakes to type 3 nonces is smaller than to type 1 and 2 nonces.

Table 10. Proportions of incorrect answers of nonces in Experiment 2

| Type | Incorrect |
|------|-----------|
| Type 1 (bøt) | 481 (32%) |
| Type 2 (bøt) | 478 (31%) |
| Type 3 (føst) | 327 (21%) |

The data in table 10 were analyzed in a logistic mixed effects model with accuracy as dependent variable and with Type as fixed effect, and random slopes for items and participants. The analysis confirms that nonces of type 1 and 2 are judged equally accurately, whereas nonces of type 3 are judged with greater accuracy, as is illustrated in table 11.

We expected that the source of support mattered and that nonces that are supported by an inflected form are treated differently from nonces that have support from a diminutive. It turns out, though, that nonces of type 1 and type 2 are both mistaken for words to the same extent, but differently from type 3.

\(^2\) Releveling of our factors showed that this Type 1 and 2 and indeed the same and that they are different from type 3.
Table 11. Logistic regression analysis of the accuracy of the judgements of the participants to nonces in experiment 2

|                         | Estimate | Std. Error | z value | Pr(>|z|) |
|-------------------------|----------|------------|---------|----------|
| (Intercept = type 1)    | 1.02     | 0.31       | 3.32    | 0.00     |
| Type 2                  | 0.02     | 0.19       | 0.12    | 0.90     |
| Type 3                  | 1.04     | 0.20       | 5.16    | 0.00     |

Let us turn to the analysis of the reaction times. The results of a linear mixed effects model with the logarithm of the Reaction time as dependent variable and Type (type 1, type 2, type 3), is presented in Table 12. Item and Participants were given random slopes.

Table 12. Linear regression analysis of the log-transformed response latencies of the judgements to correctly accepted words in experiment 2

|                         | Estimate | Std. Error | df | t value | Pr(>|t|) |
|-------------------------|----------|------------|----|---------|---------|
| (Intercept = type 1)    | 6.36     | 0.05       | 129.05 | 120.31 | 0.00    |
| Type 2                  | 0.13     | 0.06       | 86.82 | 2.26    | 0.03    |
| Type 3                  | 0.10     | 0.06       | 86.61 | 1.75    | 0.08    |

Words of type 2 are reacted to slower than words of type 1, and words of type 3 are reacted to a bit slower, but not significantly, than words of type 1. An analysis in which the fixed factor was releveled so as to make type 2 the intercept (the analysis is not shown here), showed that the difference between type 2 and type 3 words is not significant. The reaction time data, too, show that type 1 and type 2 are different from type 3 words.

We also analyzed the accuracy data of incorrectly accepted nonces, that we have presented in table 10. The participants thought erroneously that these were words and in that case the paradigm may have been activated to influence the reaction times.

The results of a linear mixed effects model with the logarithm of the Reaction time as dependent variable and Type (type 1, type 2, type 3), as fixed factor, and random slopes for Items and Participants is presented in table 13. The analysis shows that the reaction times to items of type 2 and 3 are slightly, but significantly, faster than reaction times to items of type 1.

Table 13. Linear regression analysis of the log-transformed response latencies of the judgements to incorrectly accepted nonces in experiment 2

|                         | Estimate | Std. Error | df | t value | Pr(>|t|) |
|-------------------------|----------|------------|----|---------|---------|
| (Intercept = type 1)    | 6.72     | 0.04       | 75.80 | 178.83 | 0.00    |
| Type 2                  | -0.08    | 0.03       | 78.04 | -2.94  | 0.00    |
| Type 3                  | -0.08    | 0.03       | 100.87 | -2.69  | 0.01    |

Nonce words of type 1 are supported by an inflected form, while nonce words of type 2 are supported by a derived form, and nonce words of type 3 have no support at all in their word family. The reaction time analysis indicate that having support from an inflected form in the word family makes the reaction times slower than having support from a derived form or no support at all.

In combination with the analysis of accuracy, the data indicate that participants are the accuracy of their judgements is not affected by the source of support for a nonce (table 11), but the source of support does affect the time they need to take their erroneous decision. the influence of word forms in a word family is
not equal from all forms to all other forms, as a list interpretation of the representation of paradigms in the
mental lexicon would lead us to believe.

4 DISCUSSION

On the basis of the findings of Schriefers et al. [1992], Ernestus and Baayen [2007b], we set out to
investigate two questions. This first was whether word forms that are morphologically related influence
each other’s recognition, even if they differ in a complete phoneme. The second was whether inflectionally
related words exert more influence on each other than derivationally related words on inflected words.

In a first lexical decision experiment we assessed whether nonces that differ in one phoneme and have
support from two word forms in the word family are treated differently from nonces that differ from words
in one phoneme and have support from one word form, or whether they are treated differently from nonces
without any support. We used nouns of three subtypes of the same inflectional class. In the first subtype
the plural form has a front vowel (Bart ‘beard, sg.’ and Bärte ‘beard, pl.’); the second subtype has a back
vowel in the plural (for example Boot ‘boat, sg.’ and Boote ‘boat, pl.’); the third subtype has a front vowel
in the singular and the plural (Fest ‘party, celebration sg.’ and Feste ‘party, celebration, pl.’). All three
subtypes have diminutives with front vowels: Bärtchen ‘little beard’, Bötchen ‘little boat’, and Festchen
‘little party, celebration’. The word forms in these word families sometimes differ by one phoneme, for
example vowel in the the singular of Bart is back and its counterpart in the plural is front Bärt. We used the
diminutives to investigate whether inflected forms (singulars and plurals) affect each other more strongly
than inflected forms affect derived forms (singulars and plurals as opposed to diminutives.)

We expected that, if morphology plays a role in word recognition, the nonces with support from word
forms in the word family would be more likely to be mistaken for a word. As a consequence, such a nonce
would be more likely to be erroneously accepted as a word (type 1 nonces in experiment 1). Moreover,
we expected that the source of support would affect the reaction times and the accuracy to judgements of
nonces, since we hypothesize that not all words forms in a word family affect each other to the same extent.

These expectations were borne out. Participants were more likely to mistake a nonce for a word if the
phonological make up of a nonce was supported by two word forms in the word family (see table 4 and 7).
However, as the participants made relatively few mistakes, the reaction time data do not allow us a firm
conclusion, even though the tendency in the data hints at a faster decision in case a nonce is supported by
two forms in the word family. We extend the results from Schriefers et al. [1992], Ernestus and Baayen
2007b) by showing that even morphologically related word forms that differ in one phoneme affect each
other’s response latencies, provided they are morphologically related.

In a second lexical decision experiment we assessed whether a derived item exerts less influence on an
inflected item, than inflected items on each other. We expected that a nonce that resembles an inflected
form would be more likely to be mistaken for a word than when a nonce resembled a derived form (type 1
and 2 nonces in experiment 2). Moreover, we expected that the difference in response latencies of incorrect
reactions to a nonce that resembles an inflected form are different than the response latencies of incorrect
answers to a nonce that resembles a derived form (type 1 and 2 nonces in experiment 2).

The expectations were partially borne out. Nonces that are similar to an inflected word are mistaken for
a word as often as nonces that are similar to a derived word. This shows that derived words do indeed
influence inflected words and that inflected words influence each other, but not that the strength of the
influence is determined by the source of the influence. However, the response latencies show that a nonce

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that has support from an inflected form (nonces of type 1) take longer to be erroneously accepted as a word
than a nonce that has support from a derived form (type 2) or a nonce that has no support (type 3).

In combination the results show that morphologically related word forms that differ in a vowel phoneme
affects each other, and that the influence of word forms in a paradigm is not equal: Inflected word forms
exert a stronger influence on each other than a derived word form on an inflected word form. In short, the
results of experiment 1 and 2 together suggest that the frame representation proposed in figure 5 is on the
right track.

These results are reflected in the frame representations (see figures 1, 2, 3, 4 and 5): inflected forms share
a central node and influence each other more strongly. The influence of derived words on inflected words is
smaller because they do not share a central node with inflected word forms.

Ernestus and Baayen (2007b) showed that both inflected words and derived words influence each other,
but their items were almost identical and differed only in subphonemic detail. This, it may turn out, is a
crucial difference with our study. in order for derived forms to exert a greater influence on inflected forms
it may be necessary for them to not only resemble the inflected words semantically, but also phonologically
and phonoetically. This would also extend to the results of Schriefers et al. (1992).

Our results support network models in which word forms are organized according to morphological
affiliation, and phonological and semantic similarity. We have made the morphological organization more
specific to include the difference between inflection and derivation as a difference between the referential
node within a concept. In processing this difference is reflected by the fact that the influence of inflected
words on each other is stronger than the influence of derived forms on inflected forms. Moreover, we have
provided an argument to further incorporate word families in models of word recognition.

Moreover, by proposing a frame representation we have connected the psycholinguistically motivated
network models (Schriefers et al., 1992; Schreuder and Baayen, 1995) with attribute-value models (Bonami
and Crysmann, 2016), in general and frame models in particular (Gamerschlag et al., 2013; Löbner, 2014;
Andreou, 2018).

5 CONCLUSION

Our experiments provided further evidence that the mental lexicon is organized along morphological lines.
Much evidence in the literature shows that derived word forms themselves for networks of related derived
word forms (Lehtonen et al., 2007; Moscoso del Prado Martín et al., 2004; Schreuder and Baayen, 1997;
Schriefers et al., 1992; Vannest et al., 2002). Our results extends these findings to inflectionally related
word forms and further entrench the theory that inflectionally related words are also represented as a
network. This provides evidence for a network of paradigmatic relations, that we represented as a frame in
figures 1, 2, 3, 4 and 5. Inflectionally related forms share a referential node, while in derived words the
referential node is a different one.

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial
relationships that could be construed as a potential conflict of interest.
AUTHOR CONTRIBUTIONS

RvdV: Conception, Design, Analysis, Writing
DBH: Design, Analysis, Writing

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ETHICS COMPLIANCE STATEMENT

According to information obtained from Dr. H. Weyerts-Schweda (Deutsche Forschungsgemeinschaft), no approval is required for behavioral experiments (reaction time) using standard psycholinguistic stimulus materials (auditorily presented words) without any aversive or emotionally arousing materials.

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APPENDIX I. FREQUENCY

As frequency differences among words affect their processing (Baayen et al., 2003), we established the frequencies of the words in our experiments. We estimated their frequency by using the frequencies of these words in the SdeWaC corpus (Faaß and Eckart, 2013). This corpus was created by parsing all sentences from all websites that end in ‘.de’ (Baroni et al., 2009). Shaoul and Tomaschek (2013) then used this corpus to establish the frequency of the words in CELEX (Shaoul and Tomaschek, 2013) that occur in the SdeWaC corpus. Our estimates are based on the occurrences of words in CELEX, but with the more recent frequency counts of the SdeWaC corpus.

We did not find frequency information of all words, in fact for 21% of our data we did not find frequency information (we did not find frequency information on 32% of Type 1 nouns, 19% of Type 2 nouns and 13% of Type 3 nouns).

We these caveats in mind, we calculated a regression model with Number (singular or plural) and Type (Type 1, Type 2 and Type 3) as predictors of the frequency per million. As can be seen in table 14 no main effect nor any interactions reached significance.

|                  | Estimate | Std. Error | t value | Pr(>|t|) |
|------------------|----------|------------|---------|----------|
| (Intercept)      | 0.17     | 3.14       | 0.05    | 0.96     |
| Type 2           | 7.46     | 4.34       | 1.72    | 0.09     |
| Type 3           | 7.22     | 4.34       | 1.66    | 0.10     |
| Plural           | -0.14    | 4.93       | -0.03   | 0.98     |
| Type 2 * Plural  | -7.24    | 6.55       | -1.11   | 0.27     |
| Type 3 * Plural  | -6.12    | 6.48       | -0.94   | 0.35     |

Table 14. Statistical comparison of the frequencies of the different type of words in our experiments.

In short, the frequencies if the three types of nouns in our experiments is comparable and any effect that we may find is attributable to factors other than (or, perhaps more accurately, in addition to a similar) frequency effect.

APPENDIX II. NEIGHBORHOOD DENSITY

An inhibitory effect is found among words that are phonologically or phonetically similar, and which do not stand in a morphological relationship to each other. The similarity among words can be measured in
several ways (Gahl and Strand, 2016), but often it is done in terms of phonemes. Words that differ one phoneme are called neighbors (Luce, 1985; Gahl and Strand, 2016). For example, the words sling and fling are neighbors. The response latencies to words with many neighbors is slowed down in comparison to words with a few neighbors (Luce, 1985; Luce and Pisoni, 1998; Pisoni et al., 1985). To ensure that the effects we found can indeed be ascribed to morphology and not on an effect of neighborhood density, we calculated the neighborhood density of our items. We created a data set of German word forms of nouns, verbs and adjectives by extracting 355,625 nouns from the CELEX corpus (Baayen et al., 1995; Shaoul and Tomaschek, 2013). We then created a list that contained all words that we used in our experiments; all singulars, plurals and diminutives. We then used the data set to calculate, for each word in our experiment, how many neighbors each had by using (Hall et al., 2015). For each word in our experiment we counted as neighbor each word in the data set that differed by one phoneme from the experimental word (Vitevitch and Luce, 1999). For example, we found that Krug ‘mug’ has 4 neighbors: Krugs ‘mug GEN’, trug ‘bear PST’, klug ‘smart’ and Krieg ‘war’. We then used the density in a regression analysis. The density of plurals and singulars is higher than the density of diminutives, but other than that the density are comparable. It is therefore unlikely that differences in neighborhood density among our words have contributed much to our results.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Estimate} & \text{Std. Error} & \text{t value} & \text{Pr(>|t|)} \\
\hline
\text{(Intercept = Diminutive Type 1)} & 2.97 & 1.44 & 2.06 & 0.04 \\
\text{Plural} & 13.67 & 2.04 & 6.70 & 0.00 \\
\text{Singular} & 11.93 & 2.04 & 5.85 & 0.00 \\
\text{type 2} & -1.90 & 2.04 & -0.93 & 0.35 \\
\text{type 3} & -2.47 & 2.04 & -1.21 & 0.23 \\
\text{Plural \times type 2} & 3.33 & 2.88 & 1.16 & 0.25 \\
\text{Singular \times type 2} & 4.03 & 2.88 & 1.40 & 0.16 \\
\text{Plural \times type 3} & 4.93 & 2.88 & 1.71 & 0.09 \\
\text{Singular \times type 3} & 2.87 & 2.88 & 0.99 & 0.32 \\
\hline
\end{array}
\]

APPENDIX III. MATERIAL

There are other methods of establishing neighborhoods (Gahl and Strand, 2016), and we tried them but our results remain the same.
| Item   | translation | exp.1 word (sg) | exp. 2 word (pl) | exp. 1 nonce | exp. 2 nonce |
|--------|-------------|-----------------|------------------|--------------|--------------|
| Gans   | goose       | gans            | gEnz@            | gEns         | ganz@        |
| Hand   | hand        | hand            | hEnt             | hent         | hando        |
| Luft   | air         | loft            | lyft             | lyft         | luft          |
| Saft   | juice       | zaft            | zeft             | zeft         | zaft         |
| Wand   | wall        | vant            | vEnt             | vEnt         | vando        |
| Wolf   | wolf        | volf            | velf             | volf         | volf         |
| Bart   | beard       | baet            | bEnt             | bEnt         | baeto        |
| Korb   | basket      | kœep            | kœep             | kœep         | kœep         |
| Marsch | march       | maef            | mœef             | mœef         | mœef         |
| Wurf   | throw       | vœef            | vœef             | vœef         | vœef         |
| Ball   | ball        | bal             | bel              | bel          | balo         |
| Bauch  | stomach     | bœux            | bœux             | bœux         | bauxo        |
| Baum   | tree        | bœym            | bœym             | bœym         | bauemo       |
| Damm   | dam         | dam             | dem              | dem          | damo         |
| Fuss   | foot        | fœss            | fœss             | fœss         | fœss         |
| Fluch  | curse       | flux            | fly:ç            | fly:ç        | fly:ç         |
| Kauz   | fogey       | kœuts           | kœuts            | kœuts        | kœuts        |
| Krug   | jug         | kœyk            | kœyk             | kœyk         | kœyk         |
| Laus   | louse       | laus            | lœys             | lœys         | lœys         |
| Maus   | mouse       | maos            | mœys             | mœys         | mœys         |
| Rang   | rank        | ra5t            | ra5t             | ra5t         | ra5t         |
| Zahn   | tooth       | tsan            | tœsn             | tœsn         | tœsn         |
| Saal   | hall        | zaUx            | bOYç             | bOYç         | baucho       |
| Beck   | beck        | bœxm            | bœym             | bœym         | bauemo       |
| Saum   | seam        | zaUom           | bOYm             | bOYm         | bauemo       |
| Schwan | swan        | fœan            | fœan             | fœan         | fœan         |
| Schwung| momentum    | fœan            | fœan             | fœan         | fœan         |
| Stall  | shed        | fœal            | fœal             | fœal         | fœal         |
| Zoll   | custom      | tsœl            | tsœl             | tsœl         | tsœl         |
| Zopf   | plait       | tsœpf           | tsœpf            | tsœpf        | tsœpf        |
### Table 16. Target type 2 items

| Item | translation | exp.1 word (sg) | exp. 2 word (pl) | exp. 1 nonce | exp. 2 nonce |
|------|-------------|-----------------|-----------------|-------------|-------------|
| Docht | wick        | doxt            | doxt            | doxt        | doxt        |
| Dolch | dagger      | dołć            | dołć            | dołć        | dołć        |
| Fund  | find        | fond            | fond            | fynt        | fynt        |
| Kult  | cult        | kółt            | kółt            | kult        | kult        |
| Mast  | mast        | mast            | mast            | mesta       | mesta       |
| Pult  | desk        | półt            | półt            | pultz       | pultz       |
| Salz  | salt        | zalts           | zalts           | zelts       | zelts       |
| Takt  | beat        | takt            | takt            | tekst       | tekst       |
| Luchs | lynx        | loks            | loks            | lyks        | lyks        |
| Kurs  | class       | koes            | koes            | kyres       | kyres       |
| Boot  | boat        | boťt            | boťt            | boťt        | boťt        |
| Boss  | boss        | boś            | boś             | boś         | boś         |
| Bus   | bus         | bus             | bus             | bvs         | bvs         |
| Gas   | gas         | gaz             | gaz             | g:z:s        | g:z:s        |
| Huf   | hoof        | huf             | huf             | h:uf        | h:uf        |
| Kohl  | kale        | kořl            | kořl            | kořl        | kořl        |
| Pol   | pole        | pold            | pold            | pold        | pold        |
| Ruf   | call        | ruf             | ruf             | ryf:s        | ryf:s        |
| Schaf | sheep       | jařf            | jařf            | jeř:f        | jeř:f        |
| Tag   | day         | takt            | takt            | t:ek        | t:ek        |
| Tod   | death       | tořt            | tořt            | tořt        | tořt        |
| Haar  | hair        | h:are           | h:are           | h:are       | h:are       |
| Pfad  | path        | pf:at           | pf:at           | pf:at       | pf:at       |
| Paar  | pair        | pæ:r            | pæ:r            | pæ:r        | pæ:r        |
| Tor   | gate        | to:re           | to:re           | to:re       | to:re       |
| Brot  | bread       | brot            | brot            | brot        | brot        |
| Knall | bang        | knal            | knal            | knel        | knel        |
| Schluck | swallow | flouk          | flouk          | flyk      | flyk      |
| Stoff | fabric      | ftaf            | ftaf            | ftaf        | ftaf        |
| Flur  | hall        | flure           | flure           | flyre       | flyre       |

This is a provisional file, not the final typeset article
### Table 17. Target type 3 items

| Item | translation | exp.1 word (sg) | exp. 2 word (pl) | exp. 1 nonce | exp. 2 nonce |
|------|-------------|-----------------|------------------|--------------|--------------|
| Fest | celebration | fest            | fEst             | fEst         | fEst         |
| Film | film        | film            | fIlm             | fIlm         | fIlm         |
| Heft | notebook    | heft            | hEft             | hEft         | hEft         |
| Hirm | brain       | hren            | hren             | hren         | hren         |
| Hirsch | deer    | hnef            | hnef             | hnef         | hnef         |
| Keks | cookie      | ke:ks           | ke:ks            | ke:ks        | ke:ks        |
| Kelch | goblet     | kElc            | kElc             | kElc         | kElc         |
| Lift | lift        | lift            | lift             | lift         | lift         |
| Pferd | horse      | pfEr            | pfEr             | pfEr         | pfEr         |
| Wirt | host        | vnet            | vnet             | vnet         | vnet         |
| Dieb | thief       | dip             | dip              | dip          | dip          |
| Fett | fat         | fet             | fet              | fet          | fat          |
| Fisch | fish       | fift            | fift             | fift         | fift         |
| Kitz | fawn        | kIts            | kIts             | kIts         | kIts         |
| Reiz | stimulus    | barts           | barts            | barts        | barts        |
| Ring | ring        | ring            | ring             | ring         | ring         |
| Sieb | sieve       | zipt            | zipt             | zipt         | zipt         |
| Sinn | sense       | zin             | zin              | zin          | zin          |
| Tisch | table      | tif             | tif              | tif          | tif          |
| Pott | mug         | pot             | pot              | pot          | pot          |
| Schuss | shot      | jos             | jos              | jos          | jos          |
| Sohn | son         | zon             | zon              | zon          | zon          |
| Wall | rampart     | val             | val              | val          | val          |
| Rock | skirt       | rake            | rake             | rake         | rake         |
| Zug | train       | tsuk            | tsuk             | tsuk         | tsuk         |
| Stier | bull      | ftrn            | ftrn             | ftrn         | ftrn         |
| Trieb | instinct   | tri:np          | tri:np           | tri:np       | tri:np       |
| Zweig | branch     | tsvo:k          | tsvo:k           | tsvo:k       | tsvo:k       |
| Blick | gaze        | blik            | blik             | blik         | blik         |
| Brief | letter      | bri:f           | bri:f            | bri:f        | bri:f        |
| sg form | translation | sg form | translation | sg form | translation | sg form | translation |
|---------|-------------|---------|-------------|---------|-------------|---------|-------------|
| Blech   | iron sheet  | Blitz   | lightning   | Gleis   | track       | Greif   | giffin      |
| Greis   | old man     | Knick   | bend        | Kreis   | circle      | Kreuz   | cross       |
| Krieg   | war         | Preis   | price       | Schlitz | grove       | Schmied | smith       |
| Schrein | shrine      | Schwein | pig         | Spiel   | game        | Spie§   | skewer      |
| Spitz   | spitz       | Steg    | runway      | Stein   | stone       | Stiel   | handle      |
| Stil    | style       | Stück   | piece       | Zweck   | purpose     | Gnom    | gnome       |
| Brauch  | custom      | Bratt   | bride       | Drahf   | wire        | Flug    | flight      |
| Fluss   | river       | Frosh   | frog        | Gruss   | greeting    | Klang   | sound       |
| Kloß    | dumpling    | Klotz   | brick       | Knopf   | button      | Pflock  | plug        |
| Pflug   | plough      | Plan    | plan        | Platz   | place       | Schlauch| pipe        |
| Schluss | end         | Schwamm| sponge      | Span    | blade       | Spass   | joke        |
| Stab    | bar         | Stadt   | chair       | Traum   | dream       | Stock   | stick       |
| Stoß    | kick        | Stuhl   | gene        | Keil    | liner       | Zwang   | bondage     |
| Schwur  | vow         | Gen     | leg         | Pass    | passport    | Pfeil   | arrow       |
| Busch   | bush        | Hut     | hat         | Bier    | beer        | Beet    | bed         |
| Beil    | axe         | Bein    | thing       | Fell    | coat        | Biss    | bite        |
| Deich   | dyke        | Ding    | Hecht       | Keim    | germinal    | Föhn    | blow-dryer  |
| Gel     | gel         | Hain    | grove       | Klopf   | high bar    | Heer    | army        |
| Heim    | home        | Hieb    | flourish    | Keim    | Schein      | Laib    | loaf        |
| Meer    | sea         | Netz    | net         | Schein  | pond        | Reim    | rhyme       |
| Riss    | crack       | Scheich | sheik       | Schein  | way         | Schiff  | ship        |
| Sieg    | victory     | Speer   | javelin     | Teich   | way         | Teig    | dough       |
| Teil    | part        | Tier    | animal      | Weg     | way         | Wein    | wine        |
| Zeug    | stuff       | Ziel    | goal        | Bass    | bass        | Fang    | catch       |
| Gaul    | horse       | Guss    | shower      | Hang    | slope       | Haut    | skin        |
| Hof     | court       | Kahn    | barge       | Kamm    | comb        | Koch    | chef        |
| Kopf    | button      | Lauf    | run         | Lohn    | wage        | Naht    | fissure     |
| Nuss    | nut         | Pfahl   | pale        | Rat     | tone        | Raum    | room        |
| Satz    | sentence    | Schopf  | tuft        | Ton     | year        | Topf    | pot         |
| Zaun    | fence       | Chor    | choir       | Jahr    | Recht       | Recht   | law         |
| Vers    | verse       | Mönch   | monk        | Berg    | mountain    | Feind   | enemy       |
| Gift    | poison      | Gips    | cement      | Helm    | helmet      | Herd    | stove       |
| Kerl    | fellow      | Kern    | nucleus     | Nerz    | mink        | Pelz    | fur         |
| Pilz    | mushroom    | Rest    | rest        | Schelm  | rascal      | Scherz  | joke        |
| Schild  | shield      | Schirm  | umbrelia    | Term    | term        | Werk    | work        |
| Wert    | value       | Wicht   | goblin      | Wind    | wind        | Wink    | cue         |
| Witz    | joke        | Zelt    | tent        | Dachs   | badger      | Halm    | blade       |
| Hund    | dog         | Farn    | brake       | Molch   | newt        | Mond    | moon        |
| Barsch  | perch       | Garn    | twine       | Gurt    | belt        | Hort    | hoard       |
| Lurch   | amphibian   | Mord    | murder      | Dampf   | steam       | Duft    | smell       |
| Faust   | fist        | Fuchs   | fox         | Gast    | guest       | Hals    | neck        |
| Kampf   | battle      | Lust    | desire      | Macht   | power       | Magd    | maidservant |
| Nacht   | night       | Rumpf   | body        | Schacht | chamber     | Schaft  | bootleg     |
| Schatz  | treasure    | Sucht   | addiction   | Sumpf   | swamp       | Tanz    | dance       |
| Wunsch  | wish        | Darm    | bowel       | Sarg    | coffin      | Turm    | tower       |