“Fake” gemination in suffixed words and compounds in English and German

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ABSTRACT

In languages with an underlying consonantal length contrast, the most salient acoustic cue differentiating singletons and geminates is duration of closure. When concatenation of identical phonemes through affixation or compounding produces “fake” geminates, these may or may not be realized phonetically as true geminates. English and German no longer have a productive length contrast in consonants, but do allow sequences of identical consonants in certain morphological contexts, e.g., suffixation (*green-ness; zahl-los* “countless”) or compounding (*pine nut*; *Schul-leiter* “headmaster”). The question is whether such concatenated sequences are produced as geminates and realized acoustically with longer closure duration, and whether this holds in both languages. This issue is investigated here by analyzing the acoustics of native speakers reading suffixed and compound words containing both fake geminate and non-geminate consonants in similar phonological environments. Results indicate that the closure duration is consistently nearly twice as long for fake geminates across conditions. In addition, voice onset time is proportionally longer for fake geminates in English while vowel duration shows few significant differences (in German sonorants only). These results suggest that English and German speakers articulate fake geminates with acoustic characteristics similar to those found in languages with an underlying length contrast, despite no longer displaying the contrast morpheme-internally.

INTRODUCTION

Many of the world's languages contrast singleton and geminate consonantal phonemes (e.g., Bengali [kana] “blind” – [kan:a] “tears”). This contrast, which could also be characterized as a short-long contrast, is not restricted to particular language families, but instead is extremely widespread; being attested, for example, in Bengali, Berber, Finnish, Italian, Leti, Pattani Malay, Swiss German, and Turkish (Lahiri and Hankamer, 1988; Esposito *et al.*, 1999; Hume *et al.*, 1997; Abramson, 1987; Kraehenmann, 2001; Ridouane, 2007). Typically, the geminate-singleton contrast occurs in word-medial position, but contrasts in word-final and even word-initial position are also attested (cf. Hume *et al.*, 1997; Kraehenmann and Lahiri, 2008; Ridouane, 2010).

Our focus here is on languages which had lexical (underlying) geminates in the medieval period (until the 17th century) but have undergone degemination in all lexical words. Thus, a contrast such as between Old English *sunu* “son” and *sunne* “Sun” was lost in Middle English (henceforth ME), and the corresponding Old High German (OHG) contrast between *sunu* “son” and *sunna* “Sun” was also lost in Middle High German. After the loss of the final schwa, the modern English equivalents *Sun* and *son* now form a homophonous pair pronounced [sʌn] while in German they are *Sohn* “son” [zo:n] and *Sonne* “Sun” [zɔnə]. However, it remains unclear whether a sequence of identical consonants in a morphologically complex word continues to be long or has also been degeminated. For example, in ME the nasal /n/ in the adjective *clean* gives rise to a geminate when the suffix *–ness* is added but remains a singleton when followed by a vowel-initial inflectional suffix (e.g., *–es*), e.g., ME *clæ*——æ¯*nness* “cleanness” vs *clæ*——æ¯*nes* “clean.neut-gen.” The question we ask here is whether the degemination rule also affected geminates in morphologically complex words. Furthermore, the same question arises for compounds where two lexical words form a single prosodic unit (cf. Wheeldon and Lahiri, 2002): Is the nasal /n/ in compounds such as *pine nut* realized as a geminate or a singleton? In Old English such a compound would have contained a geminate consonant (e.g., cf. Lass and Anderson, 1975).

Previous analyses of consonant length have investigated the difference between underlying lexical geminates and concatenated geminates but only in languages which have a singleton-geminate contrast at a lexical level. The phenomenon addressed by this paper is that seen in languages like English and German, which lack this lexical geminate-singleton contrast, yet present sequences of identical consonants via morpheme concatenation, either through suffixation (*clean-ness; zahl-los* “countless, lit. number-less”) or compounding (*bank card*; *Zahn-nerv* “tooth-nerve”). All of these consonantal sequences would have been geminates at earlier stages of both languages. In line with previous literature (e.g., cf. Oh and Redford, 2012) we refer to these consonantal sequences as “fake geminates” since consonantal duration is not otherwise contrastive in present-day English or German.

While German is said to have undergone degemination to a greater extent (cf. Wiese, 1996, p. 229ff.), substantial degemination took place in both languages and eliminated all lexical geminates. In present-day English, identical adjacent segments resulting from prefixation with, for example, *in-* and *un-* have been shown to still lead to gemination (cf. Oh and Redford, 2012) while in German prefixes result in mandatory degemination (cf. Wiese, 1996, p. 231). However, while some suffixes in German also result in mandatory degemination (e.g., the diminutive suffix *–lein*), others (e.g., *–los*) and adjacent segments resulting from compounds do not and gemination here is more variable (cf. Wiese, 1996, p. 231). To what extent the process of degemination has had an effect, beyond underlying geminates, on the status of the present-day sequences of identical consonants which arise due to affixation or compounding in the two languages, has not yet been explored experimentally.

When two identical consonants become adjacent through concatenation, we find four attested possibilities across languages of the world. The first option is that the sequence of identical consonants is broken up by syncope as is the case, for example, in the English past tense or plural forms where stem-final consonants are identical to those of the affix (e.g., *wed-d* > *wedded*, *rose-z* > *roses;* cf. *beg-d*, *bag-z*). Alternatively, one of the consonants changes, for example, its manner of articulation (e.g., Vk-kV > VxtV; Tigrinya in Hayes, 1986, p. 336). The third option is the deletion of one of the two segments which results in a singleton (e.g., English *meet-t* > *met* with concomitant vowel shortening; English *innumerable* [ɪnju:məɹəbl]; Dutch *aan-name* "assumption" [anamə]). Finally, the fourth option is to maintain the identical sequence and create a geminate.

Gemination is thus not an automatic process which occurs as a matter of course when two identical segments become adjacent. As it is already evident from the examples above, English uses several of these mechanisms to deal with such sequences in different contexts.[1] Furthermore, identical sequences can come about in different word types, for example, as a result of affixation or compounding. The overarching aim of this study is to establish how English and German deal with adjacent identical segments which result from concatenation in the following different environments: affixed words, compounds, and phrases. The precise questions we are asking are the following:

(1) Given that there are a number of options for dealing with adjacent identical segments, which one is prioritized by English and German? Are identical sequences in English and German treated as short or long, or are they broken up or is one segment deleted?

(2) To what extent do the realizations of sequences of identical consonants differ depending on whether these sequences occur in compounds or affixed words?

(3) As English and German differ in their historical treatment of identical consonant sequences, what differences occur across these categories synchronically?

(4) If gemination is the process applied to adjacent identical segments, do these "fake geminates" have similar acoustic characteristics to underlying geminates in languages with a lexical geminate/singleton contrast?

The reason for examining affixed words and compounds is that while they are structurally different, in terms of post-lexical phonological word formation these have the same status: both have been shown to form a single prosodic unit (Selkirk, 1982; Gussenhoven, 1986; Wheeldon and Lahiri, 2002). Prosodic words can be affixed items consisting of stems and affixes, as well as compounds which are formed recursively such that two prosodic words are combined to form a single prosodic word with the main stress aligned with the leftmost foot. Experiments in language production have shown that native speakers consider affixed words (e.g., *cleanness*) and compounds (e.g., *pine nut*) to be equivalent in terms of phonological encoding (cf. Wheeldon and Lahiri, 2002; Wynne, 2015). Phrases with adjacent identical segments (e.g., *clean nest*), on the other hand, are considered two independent prosodic words (cf. Table I) and a difference in relative duration between word-internal and word-boundary geminates has been shown in a previous study (Oh and Redford, 2012).

Acoustic properties of geminates

Over the last decades, a considerable literature has emerged on the phonetic characteristics of geminates. Acoustically, "true" geminate consonants are single consonants in the sense that they have a single release and cannot, therefore, be considered a cluster of consonants. The predominant acoustic cue for intervocalic geminates across languages is a longer duration of closure than is observed for singleton consonants (cf. Abramson, 1986; Lahiri and Hankamer, 1988; Kraehenmann, 2001; Ridouane, 2010). If the contrast involves voiced stops (oral or sonorant), then the acoustic manifestation is longer vocal cord vibration before release. If, however, the geminate is a voiceless stop or affricate, then the acoustic correlate is a longer period of silence during vocal tract closure. There can be additional cues, such as shorter vowel duration (VD) before geminates than before singletons (cf. Kraehenmann and Lahiri, 2008; Ridouane, 2010) or qualitatively different release characteristics (cf. Arvaniti and Tserdanelis, 2000; Payne, 2006), but these differences are often not significant, nor are they always consistent.

In Ridouane's (2010, p. 65) review of 24 languages with lexical geminates, the only significant cue to the geminate-singleton contrast found across all of them was longer duration of closure in geminates. The same review finds only four languages that have a significant difference in the duration of preceding vowels, out of a total of 13 languages for which data were available. Such evidence contradicts the claim made by Maddieson (1985, p. 212) that "all the languages for which data is to hand show the occurrence of a shorter vowel in a syllable closed by a geminate consonant," a notion that is, in turn, given as evidence for a purported universal status for closed syllable vowel shortening.

The heteromorphemic sequences of identical consonants which we find in English and German, and which are often described as "fake" geminates (Kenstowicz and Pyle, 1973; Schein and Steriade, 1986; Hayes, 1986; Oh and Redford, 2012), may not always behave like "real" (lexical) geminates in every way. For instance, an underlying geminate will never allow an epenthetic vowel or pause to intervene (VC_iC_iV > *VC_iaC_iV; see Kenstowicz and Pyle, 1973, pp. 31–34, for an example from Kolami), while a concatenated geminate can permit vowel or gap insertion ($VC_i\text{-}C_iV_{suffix}$ > $VC_iaC_iV_{suffix}$). Alternatively, consonants of a fake geminate cluster may undergo deletion or feature alternation (e.g., Vk-kV > VxtV; Tigrinya in Hayes, 1986, p. 336), while an underlying geminate always changes as a single consonant. Nevertheless, in languages where a real singleton-geminate contrast occurs, such heteromorphemic sequences can behave phonologically like real geminates, as in Bengali; compare [ʃoti] "lady" ∼ [ʃot:i] "truth" to [pat-t-o] "lay-past.2p" > [pat:o]. Here, the medial [t:] in [ʃot:i] and [pat:o] are phonetically and phonologically identical despite the concatenative nature of the medial geminate in [pat:o].

The question, then, is to what extent languages without lexical geminates can have heteromorphemic consonantal sequences which mirror the phonetic features of geminates in languages that do have a long-short consonantal contrast at the lexical level. To this end, we examine present-day English and German, both of which can be traced back to stages in their history where lexical geminates were a part of the phoneme inventory. As we shall see, nowadays geminates are no longer part of the lexicon and there are mechanisms blocking the occurrence of some fake geminates (e.g., the introduction of epenthetic *Fugenelemente* -s- and -ə- in words such as *Glückskatze* "lucky cat"). However, we know very little as yet about the acoustic characteristics of the fake geminates that do exist. If these sequences maintain a phonetic length contrast with singletons, then we can conclude that fake geminates have remained long. Furthermore, we ask whether these concatenated sequences display any other characteristics which have been claimed for underlying geminates—such as durational differences in the preceding vowel—and hence whether the phenomenon has a more local or a more global effect on the representation of morphologically complex words.

Fake geminates: Occurrence and previous research

Fake geminates occur either through morpheme concatenation (which may involve suffixes or prefixes) or across two lexical words in a compound. Both German and English show instances of two identical consonants across morpheme boundaries, e.g., English *meanness* and German *zahllos* "countless." Old English and Old High German geminates which were degeminated about 400 years ago are often still reflected in spelling but are now singletons, e.g., English *kissing*, *bedding* or *sunny* and German *Sonne* “Sun” or *schwimmen* “to swim.” Thus merely because words with suffixes like *–ness*, *–ly* or German *–los* are written with a sequence of identical consonants, one cannot deduce anything about their actual phonetic length. Furthermore, in English, adjectives with short vowels often appear to add a consonant in spelling when a suffix is added, irrespective of whether this creates fake geminates or not: *thin*, *thinn-er*, *thin-ness*. The study presented here, therefore, should address the issue of the phonetic reality of consonantal length in these forms.

Recently, there has been renewed interest in geminate consonants and their properties, and, in particular, in the characteristics of fake geminates in English. A useful point of comparison, bearing certain similarities to the present research, is a study by Oh and Redford (2012) which focuses on the differences between phrase-level and prefix-root boundary nasal geminates. The authors investigate the hypothesis that English may display phonetic differences between singleton consonants and fake geminates occurring word-internally (e.g., *unnamed*), on the one hand, and across word boundaries (e.g., *fun name*), on the other.

The study uses three types of stimuli: singleton medial nasals (e.g., *annoyed*), word-internal geminates through prefixation with *un-* (“concatenation,” e.g., *unnamed*) and *in-* (“assimilation,” e.g., *immeasured* [sic]) and word-boundary geminates in phrases (e.g., *one nurse*). In the analyses, both word-internal and word-boundary geminates are found to be significantly different from singletons in terms of absolute duration. In terms of relative duration (i.e., the ratio of the durations of the target consonant and the preceding vowel: C:V1), only word-internal geminates remain significantly different from singletons. These results are accounted for by the claim that the word boundaries are computed in the speech plan, resulting in a word-boundary lengthening process which, in turn, explains the longer duration of both the nasal and the preceding vowel. This interpretation is further supported by the word-boundary measurements which show a clear disjunction in the F0 contour within the word-boundary geminate, as well as pauses in an additional “careful speech” condition.

Oh and Redford (2012) conclude that geminates in their word-boundary condition exhibit phonetic characteristics that are consistent with a consonant sequence, while word-internal geminates behave similarly to lexical geminates in most cases (i.e., more so for “assimilated” than “concatenated” prefix-boundary nasal geminates). This is in line with our predictions based on the differences in prosodic word status of phrases vs prefixed morphologically complex words.

Present research

In contrast to Oh and Redford's (2012) focus on differences between phrase-level and prefix/root boundary geminates, the present research is concerned with the acoustic characteristics of fake geminates in two different types of single prosodic words (cf. Table I): the word/suffix boundary in affixed words (*-ness* and *-ly* for English and *-los* for German), and the word/word boundary in compounds (e.g., *pine nut* and *Betttuch* “bed sheet”). The study's objective is to establish whether these two closely related languages still realize identical concatenated consonants as geminates despite having undergone degemination in monomorphemic lexical word contexts or whether other processes such as degemination, syncope or changes in manner of articulation are used instead. If gemination remains the main process in these cases, we investigate whether these geminates display similar acoustic hallmarks to lexical geminates in different series of identical, concatenated consonants, and whether the different types of prosodic words show similar durations despite differences in their construction and suprasegmental properties (e.g., stress).

EXPERIMENT 1: FAKE GEMINATES IN ENGLISH

For the English experiment, we selected words with the derivational suffixes -*ness* and -*ly* as candidates for fake gemination, since these suffixes produce the largest numbers of the appropriate sequences. In counterpoint, we selected words with the suffix -*er* as being clear examples for the non-geminating condition. In parallel, we investigate the possibility of fake geminates occurring in compounds. Here, the possibilities were less restricted, and we were able to select a range of consonant sequences for the geminate condition, namely, [nn], [ll], [pp], [tt], [kk], e.g., *pen knife*, *oil leak*, *sheep pen*, *boat tour*, *bank card*, etc. (cf. Appendix A for all stimuli). These compounds (e.g., [C#C] *pine nut*) were compared toa corresponding non-geminating condition involving compounds whose second word begins with a vowel (e.g., [C#V] *pineapple*).

Method and materials

To explore geminates at the suffix boundary, we chose six single-syllable words ending in [n] which could take the suffix –*ness*, and six ending in [l] which could take the suffix –*ly*. These words were selected from a longer list on the basis of the frequency of the derived forms (CELEX frequency database for English, German and Dutch; Baayen *et al.*, 1995). All 12 test words with fake geminates had the highest frequency among the available set (see Appendix A for a list of test words). The words were presented in two conditions (cf. Table II): condition 1, with the appropriate geminating suffix (e.g., *thinness*, *palely*) and condition 2, with the non-geminating vowel-initial suffix –*er* (e.g., *thinner*, *paler*).

In order to investigate compound-boundary geminates (e.g., *pine nut*), we included the sonorants [n] and [l] (to mirror the suffixed forms), as well as the voiceless obstruents [p], [t], and [k]. We selected six high-frequency disyllabic compounds for each of the five types; where no frequency count was available in CELEX (Baayen *et al.*, 1995) or in the British National Corpus (BNC), we depended on familiarity ratings using native speaker judgments (cf. Balota *et al.*, 2001; see Appendix A for test words). As mentioned above, the second condition [C#V] included compounds with the same or a similar initial syllable followed by a vowel-initial noun (e.g., *pineapple*).

Participants

Six participants (three male and three female) were recorded at the University of Oxford, ranging in age between 20 and 39 years old (average age 24 years old). They were all speakers of Standard Southern British English. The target words were presented in black Arial size 60 on a grey background, on a 20 in. monitor approximately 60 cm away from the speaker. Each word appeared on the screen for 3 s and the participants were asked to read the words out loud as soon as they appeared. Each item appeared four times and all items were pseudo-randomized across eight blocks to allow for breaks in the recording. The words were presented across conditions (suffixed and compound words) to ensure an even distribution of all words across the test blocks. The words were recorded in a sound-attenuated recording booth on a digital voice recorder using a professional microphone, placed 40 cm away from the speaker. A total of 2016 tokens were recorded.

Analysis

Both consonant/closure duration (CD) and VD were coded for and extracted using PRAAT (Boersma and Weenink, 2014). As the ratio of the duration of the consonant to the preceding vowel (C:V1) has been claimed to be a more robust measure of consonant duration than absolute duration (cf. Pickett *et al.*, 1999; Idemaru and Guion, 2008; Oh and Redford, 2012), relative duration was also calculated. In the case of compound-boundary voiceless stops, voice onset time (VOT) was extracted in order to compare the realization of fake geminates vs singletons.

Figure 1 gives an example of a pair of derivationally suffixed words pronounced by a female speaker. Three tabs were set on each PRAAT waveform, indicating the beginning of the first vowel, the end of the vowel which coincides with the beginning of the sonorant closure, and the end of the closure. As we can see, the duration of closure for *thinness*—the geminate condition—was substantially longer than that in *thinner*—the non-geminate condition.

Figure 2 displays waveforms for a voiceless stop compound-boundary geminate alongside the non-geminate condition. Markings represent the beginning of the vowel, the beginning and end of the closure duration, and, the beginning and end of VOT. Note, once again, the longer closure for the geminate conditions.

Aside from the durational cues related to the status of geminates, pauses or gaps in the homorganic sequences were also noted, as well as clear cases of double release in plosives (cf. Fig. 3). Such forms were excluded from the general analysis, but are discussed in detail in Sec. III D in light of the more extensive tendency to introduce a pause in the German data.

Results

We used a linear mixed model (conducted with JMP11 by SAS) with *geminate* (C#C-C#V), *compound* (suffix-compound) and *geminate × compound* as fixed factors and speakers and items as random factors and with items nested under *geminate* and *compound*. As mentioned above, the variables CD, preceding VD, and relative closure duration (C:V1) were analyzed in all cases. In the compound condition, we also analyzed VOT and consonant type (sonorant vs obstruent) as separate variables.

The consonant duration analysis shows a significant difference ($R^2 = 0.80$) between C#C (163 ms) vs C#V (80 ms) items [$F(1, 101.9) = 437.87$, $p < 0.0001$] while there is no difference between the suffix vs compound conditions [$F(1, 101.9) = 0.0034$, $p = 0.954$] and neither is the interaction between the two factors significant [$F(1, 101.9) = 0.28$, $p = 0.598$]. Suffix (164 ms) and compound C#C words (162 ms) show significantly longer consonant duration than suffix and compound C#V words (79 and 82 ms, respectively).

The VD analysis shows no significant difference ($R^2 = 0.76$) between either C#C vs C#V [$F(1, 103.3) = 0.30$, $p = 0.584$] or suffixed vs compound [$F(1, 103.3) = 0.007$, $p = 0.934$] and the interaction between the two factors is also not significant [$F(1, 103.3) = 0.87$, $p = 0.353$].

It is thus not surprising that the analysis of relative closure duration ($R^2 = 0.69$) shows significance for C#C vs C#V [$F(1, 103) = 99.279$, $p < 0.0001$] while neither suffix vs compound [$F(1, 103) = 0.349$, $p = 0.556$] nor the interaction between C#C vs C#V and suffix vs compound [$F(1, 103) = 1.199$, $p = 0.276$] are significant. Figure 4 shows CD and VD for both suffixed and compound-boundary words.

Two additional linear mixed model analyses with the fixed factors *geminate* (C#C-C#V) and *consonant type* (obstruent-sonorant) with subjects and items as random as above were conducted on the compound data only. The VOT analysis for compounds with obstruent medial consonants ($R^2 = 0.75$) shows a significant difference between C#V and C#C obstruents [$F(1, 34) = 26.226$, $p < 0.0001$] with VOT significantly longer in C#C items (70 ms) than in C#V items (47 ms).

There is no significant difference in the VD ($R^2 = 0.77$) before obstruent and sonorant consonants [114 and 127 ms, respectively; $F(1, 56.01) = 2.29$, $p = 0.136$] in compound words while there is a difference in consonant duration when consonant type is taken into account. The linear mixed model ($R^2 = 0.81$) shows that sonorant consonants are significantly shorter (107 ms) than obstruents (132 ms) across both C#C and C#V words [$F(1, 55.79) = 44.78$, $p < 0.0001$]. C#C obstruents (173 ms) and C#C sonorants (146 ms) are, however, still significantly longer than their C#V counterparts [91 and 67 ms, respectively; $F(2, 55.82) = 233.41$, $p < 0.0001$]. Figure 4(b) provides an overview of the difference in vowel and consonant durations between sonorants and obstruents as well as the VOT data for obstruents.

Twenty-one tokens belonging to the geminating condition (2.9%) were excluded from the analysis as they presented a double release of the target obstruent (cf. Fig. 3). These will be discussed together with instances of this phenomenon from the German data in Sec. III D).

Discussion

Clearly, identical sequences of sonorants caused by the addition of derivational suffixes behave like geminates insofar as their acoustic characteristics are concerned. In contrast to vowel-initial suffixes, concatenated [n] and [l] sequences have significantly longer duration of closure, reminiscent of other languages with a lexical contrast including, for example, Swiss German (cf. Kraehenmann, 2001). Since there are no relevant obstruent-initial suffixes which cause fake gemination, it is difficult to generalize across other consonants and one might conclude that this lengthening characteristic is restricted to sonorants only. However, results for the compound cases confirm that fake geminates arising from concatenation also have the key acoustic characteristic of real geminates, namely, a longer realization of consonant closure. As with suffixed forms, the duration of closure is systematically and significantly longer for the [C#C] fake geminate condition in comparison with cases where the second compound element is vowel-initial, i.e., [C#V]. Since obstruents were included in this condition, it was possible to establish that the period of silence during the closure of voiceless stops was also lengthened in the geminating condition, as was the overall closure in sonorants. Thus, the lengthening observed for sonorants in the suffix condition was replicated for compounds across consonant types. Furthermore, the results show that relative closure durations are fully comparable to absolute durations, the only significant difference in the duration of the preceding vowel being a result of consonant type rather than consonant duration. These results seem to indicate that the geminate/non-geminate contrast in English is similar to that found in languages like Bengali (cf. Lahiri and Hankamer, 1988), where consonant duration is independent of changes to the preceding vowel.

EXPERIMENT 2: FAKE GEMINATES IN GERMAN

In order to place the data for English morpheme-boundary geminates within a broader cross-linguistic context, an almost identical production experiment was devised for German suffixed words and compounds. The close historical relationship of the two languages would seem to predict that such patterns would be similar; however, as noted above, there are arguments for degemination being a very widespread phenomenon in German, even occurring at compound-internal boundaries as an optional process (cf. Wiese, 1996, p. 229ff.). Contrasting the two languages should thus ultimately allow us to take a step toward determining whether morpheme-boundary geminates are subject to the same constraints in similar languages and, furthermore, whether their acoustic realization is comparable to that of "true" (lexical) geminates in languages where these exist.

In the case of suffix-boundary geminates, roots ending in [l] were examined in the context of the suffix *-los* "-less," such as *wahl-los* "indiscriminate(ly)" ("fake" geminate condition [C#C]), and when followed by a vowel-initial suffix, such as *Wahl-en* "elections-nom.pl" (singleton condition [C#V]). For compounds the same two conditions as for the English data were tested: compound-boundary geminate ([C#C], e.g., *Zahn#nerv* "tooth-nerve") and compound-boundary singleton ([C#V], e.g., *Zahn#arzt* "tooth-doctor; dentist").

Method and materials

To examine suffix-boundary geminates, a list was compiled including the six most frequent (cf. CELEX; Baayen *et al.*, 1995) -*los* suffixed words with roots ending in [l] ([C-C], e.g., *zahl-los* "countless") alongside six words with the same roots followed by a vowel-initial suffix ([C-V], e.g., *zahl-en* "pay-inf"). An example of waveforms for *zahllos* and *zahlen* can be found in Fig. 5. All suffixed words and compounds were presented together and pseudo-randomized across eight blocks.

In the compound-boundary geminate category, six different consonants were examined. As in English, the sonorants [l] and [n] and the voiceless stops [t] and [k] were used. There are insufficient appropriately lexicalized compounds with [pp] in German to match the [p] condition in the English experiment. However, the German data included two additional medial consonants: [m] and [f]. Once again, the six most frequent compounds for each of these consonants (cf. CELEX; Baayen *et al.*, 1995) were compiled in order to fit two conditions: compound-boundary geminates ([C#C], e.g., *Zahn#nerv* "tooth-nerve"), and compound-boundary singletons ([C#V], e.g., *Zahn#arzt* "tooth-doctor, dentist"). An example of the compound stimuli *Brotteller* "bread plate" and *Brotaufstrich* "spread" can be seen in Fig. 6.

A key difference between English and German is that German frequently introduces a *Fugenelement* (linking morpheme) when compounding, for example, as in *Glück#s#kind* (luck#s#child "lucky child") or *Maus#e#loch* (mouse#e#hole "mousehole"). These linking morphemes are lexically conditioned and very frequent (Plank, 1981), thus limiting the choice of compounds. As a result, although the first root in the compound was always monosyllabic, the second element (in the [C#C] and the [C#V] conditions) varied between one and two syllables since for some items there simply was no lexicalized compound with a monosyllable as the second element. In most cases the same root was used for both conditions (cf. Table III for examples). However, where this was not possible, words with identical preceding vowels were chosen. A complete list of items can be found in Appendix B.

Participants and procedure

As in the English experiment, six participants were recorded, three men and three women ranging in age between 19 and 32 years old (mean age 23 years old), all non-dialect speakers of Southern German. The experiments were conducted in Munich in quiet locations using the same recording equipment as in the English experiment. Words were presented in black Arial 60 on a grey background on a 13 in. screen placed at a comfortable distance (approximately 60 cm) from the speaker. The presentation procedure was identical to that of the English experiment, with four tokens for each word presented to each of the six speakers. A total of 2016 tokens were gathered altogether.

As in the English experiment, the measures extracted from the German recordings were absolute (CD) and relative (C:V1) consonant duration, VD, voiceless obstruent VOT and absence/presence of boundary pauses (cf. Figs. 6and 7 for examples).

Results

As in the analysis of the English data, tokens with audible gaps and double releases as well as those with mistakes (wrong or incomplete words) were excluded from the analysis (7.21% of the data). The gapped tokens are discussed separately below (see Sec. III D).

A linear mixed model with the fixed factors *geminate* (C#C vs C#V), *compound* (suffix vs compound) and *geminate* × *compound* with subjects and items as random and item nested under both geminate and compound was performed for CD, VD, and relative consonant duration (C:V1). The analysis of CD ($R^2 = 0.73$) shows significant effects for both C#C vs C#V [$F(1, 78.97) = 35.61$, $p < 0.0001$] and suffix vs compound [$F(1, 78.97) = 13.24$, $p = 0.0005$]. While C#C segments are significantly longer than C#V segments in both conditions, the compound condition overall shows much greater consonant durations (194 ms for C#C and 130 ms for C#V) than the suffixed condition (152 ms for C#C and 102 ms for C#V).

The VD data ($R^2 = 0.82$) only shows a difference in the duration of the preceding vowel for suffix vs compound [$F(1, 79.81) = 10.342$, $p = 0.0019$] while there is no significant difference between C#C and C#V [$F(1, 79.81) = 0.186$, $p = 0.668$]. Vowels in the suffixed condition are considerably longer (175 ms in C#V words and 157 ms in C#C words) than those in the compounding condition (121 and 127 ms, respectively), which is an effect of the available words in German since all words in the suffix condition contain long vowels (e.g., *zahlen* "to pay," *heilen* "to heal") while the compound condition includes words with long and short vowels.

In the relative closure duration analysis ($R^2 = 0.81$), we find that the difference in VD between the suffix and compound condition results in a significant difference for C:V1 [$F(1, 79.54) = 9.77$, $p = 0.0024$]. This can be traced back to the overall differences in vowel length between the suffixed and compound conditions. More importantly, there is also a significant difference of relative CD between C#C and C#V items [$F(1, 79.54) = 3.92$, $p = 0.05$], as was found in the English data. Figure 7 gives an overview of the results for CD and VD in the German data.

In the analyses of the compound data only [cf. Fig. 7(b) for results], the second linear mixed model ($R^2 = 0.81$) shows that, as in the English data, overall durations of sonorants (148 ms) are shorter than those of obstruents (189 ms) in both C#C and C#V conditions [$F(1, 68.01) = 38.142$, $p < 0.0001$]. The difference between C#C and C#V items remains significant in this analysis [$F(1, 68.02) = 107.70$, $p < 0.0001$]. In the VD analysis ($R^2 = 0.83$) there is no significant difference between the vowels before C#C and C#V items [$F(1, 67.2) = 0.345$, $p = 0.559$] while there is a significant difference for consonant type [$F(1, 67.2) = 22.95$, $p < 0.0001$] with vowels before sonorants being significantly longer (140 ms) than those before obstruents (93 ms).

The linear mixed model (subjects and items as random factors with item nested under C#C vs C#V) for VOT ($R^2 = 0.39$), performed only on compounds with medial voiceless obstruents (/k/ and /t/), shows no significant difference of VOT between C#C (92 ms) and C#V (79 ms) items.

Gaps or double releases in compound tokens

One particular phenomenon which was mentioned briefly in the context of the English data, and merits more detailed discussion here, is the realization of consecutive identical consonants as two separate segments. In the English data, there were 21 instances of this phenomenon (2.92% of the data) and these double releases occurred exclusively in voiceless obstruents in words of very low frequency (a frequency count of 0 or 1 in CELEX). This gapping thus seems to be a feature of low frequency compounds in a particular phonological context.

The German data, however, show a much larger proportion of these items. 121 of the fake geminate condition tokens (14.4%) were pronounced with either a gap or a double release (cf. Fig. 3). While there are a small number of these cases which affect sounds other than plosives (eg. *Nulllinie* "zero line” or *Schifffahrt* “shipping”), these could be put down to naturally occurring errors. The overwhelming majority of gaps show a clear pattern which sees them occurring mainly in the context of voiceless obstruents. In some cases, gapped realizations account for up to half the overall number of tokens for a particular word. There does not, in these cases, seem to be a clear correlation with frequency data since both relatively high-frequency words like *Dickkopf* “stubborn person” or *Betttuch* “bed sheet” and low-frequency words like *Nottaufe* “emergency baptism” or *Bluttat* “bloody deed” are affected equally. To establish this conclusively, however, a separate study would be required.

Discussion

Overall, the German data show clear similarities to the English data in both suffixed and compound conditions. Fake geminates are realized with a significantly longer consonant duration as compared to the singletons and their relative closure duration is consistently longer than that of singleton consonants. However, here are differences in absolute VD in the German data which have not been observed in the English data. This difference in VD is only significant when comparing the suffixed and compound conditions and is likely a result of a difference in vowel length of the items used. The German suffix *–los* only attaches to words with long vowels while in the compound condition there are words with both short and long vowels. When comparing C#C to C#V items, the results match those obtained for English and we find no difference in the duration of the preceding vowel.

In the analyses of the compound data, we see further similarities to the English data with sonorant durations being significantly shorter than obstruents. Again, the VD data differ from that seen in English and the preceding vowel is significantly longer before sonorants than before obstruents.

Unlike in English, the German data show more variation in the compound condition where speakers had a greater tendency to insert additional closures and releases in obstruents for compounds in the geminating condition. German speakers separated potential geminates in this way five times more often than English speakers (in 14.4% of the target words). This would be in line with the general assumption that German has a tendency to degeminate more comprehensively than English (cf. Wiese, 1996, p. 229ff.), and the frequent gaps or double releases may represent another attempt to reduce the occurrence of concatenated geminates, especially in certain phonological contexts (i.e., voiceless obstruents). One possible hypothesis is that German does indeed show greater degemination, with semantically more opaque compounds more likely to be degeminated while familiar transparent compounds show gemination and less familiar compounds are treated like phrases.

GENERAL DISCUSSION

Generally, in languages with an underlying contrast between singletons and geminates, geminates arising from concatenation behave like lexical geminates in certain ways (e.g., acoustically) but not in others (e.g., in cases of epenthesis). Phonologically, a medial geminate is always heterosyllabic—spanning the coda of the preceding syllable and onset of the following syllable—but despite being assigned to different syllables, a geminate is one single unit. The question is thus: what happens to sequences of identical consonants in languages which may have had underlying geminates in the past but where consonant duration is no longer lexically contrastive? Furthermore, would these sequences be treated similarly in different environments, i.e., in compounds, affixed words and phrases) and show similar phonetic characteristics? Would English and German show different patterns synchronically, despite significant differences in their historical treatment of geminates?

We investigated English and German speakers' production of adjacent identical segments in suffixing and compound contexts and found that gemination is the preferred resolution in these instances of concatenation in both contexts. Since suffixed items and compounds could be considered phonologically different—compounds being a phrase level phenomenon—one hypothesis would be to expect different patterns of phonetic realization of the fake geminates between these conditions. However, recall that previous research (cf. Kiparsky, 1982; Wheeldon and Lahiri, 2002; Wynne, 2015) has established morphological and phonological similarities between derivationally suffixed words and compounds from both linguistic and psycholinguistic perspectives (cf. Table I). This hypothesis would predict a similar pattern of fake gemination across the two conditions, since speakers treat both types as single prosodic units in speech production. Our data provide support for the latter hypothesis for English, with very few differences observed between the two types of fake geminates, while we find more variation in the compound condition in German with some compounds showing similar patterns to phrases.

As for the acoustic characteristics, in English, the absolute duration of closure for consonants produced by suffixing *–ness* and *–ly* to words ending [n] and [l] (e.g., *greenness*, *palely*) is consistently more than twice as long as for non-geminate closures produced by the same words with the suffix *–er* (e.g., *greener*, *paler*, see Fig. 4). These differences were also found to be significant for relative closure durations (i.e., when considered as a ratio over the duration of the preceding vowel). In a compound context, the fake geminates are again consistently more than twice the absolute length of their non-geminate counterparts (e.g., *pine nut* vs *pineapple*, Fig. 4), while remaining significantly longer in relative duration. Neither language allows concatenated geminates to occur with inflectional suffixes due to the fact that all possible candidates are single consonants (e.g., English *–s* pl or German *–t* 3sg or *–n* dat) and hence would surface in word-final position, becoming vulnerable to degemination (German: *tritt* "kick-present3sg"; *Namen* "names-dat"; cf. Wiese, 1996) or schwa insertion (English: *roses* [rəʊzəz] or *loaded* [ləʊdəd]).

Clearly, in English, degemination does not occur with identical consecutive consonants in medial positions in the derivational suffix condition and the majority of the compound items, as both of these contexts lead to the creation of fake geminates. We were constrained in our choice of consonants within suffixes, since only [n] and [l] are available in English. For compounds, however it was possible to include obstruents as morpheme-boundary consonants. Overall, the concatenated consonants led to a substantial difference in the duration of closure for all categories, very similar to what can be observed for lexical geminates in languages which have an underlying geminate-singleton contrast. Sonorant closures for [n] and [l] are significantly shorter than the silent closures for the voiceless obstruents [p], [t], and [k] in both the concatenated fake geminate and non-geminate conditions. Furthermore, obstruent closures do demonstrate a significantly longer VOT in the geminate condition in English, which follows in proportion to the increasing CD. The reason for this VOT difference, which does not occur in German, may be that the consonant is not as fully syllable-initial in case of the C#V condition as it is in the C#C condition, which would result in reduced aspiration in the former. It is generally accepted that Southern British English aspiration is closely related to syllable-onset position (cf. Gussenhoven, 1986, p. 125).

In certain languages with underlying duration contrasts (e.g., Norwegian, Italian, and Berber; cf. Ridouane, 2010, for an overview), the duration of the vowel before a real geminate is shorter than that preceding a non-geminate consonant, while other languages, such as Turkish or Bengali, show no significant difference (cf. Lahiri and Hankamer, 1988). In the English fake-geminate data, we find no significant difference in VD between geminates and singletons in either the suffixed or the compound data set, which recalls the latter group of languages where no shortening of the preceding vowel can be observed. Vowel length differences are, however, significantly affected by consonant type, with greater durations before sonorants than before obstruents.

When examining German, for which extensive degemination is claimed both in its history and in its present-day morphophonological processes (Wiese, 1996, p. 229ff.), the results are similar overall. The absolute and relative closure durations are significantly longer for [l]-final roots suffixed with -*los* than for the same roots suffixed with -*e* or -*en* (cf. *zahllos* vs *zahlen*, Fig. 7). The same significant differences are found between compounds in the geminating condition (*Zahnnerv* “dental nerve”) and in the non-geminating condition (*Zahnarzt* “dentist”) for both absolute (Fig. 7) and relative consonant duration. Unlike in the English data, VOT results for obstruents in the German compounding condition do not show significantly longer durations for geminates as opposed to singletons (cf. Fig. 7).

In the case of VD, we find that words in the suffixed condition display longer VDs overall compared to the compounds due to the predominance of long vowel words in the suffixed condition. However, there is no difference between C#C and C#V words in terms of VD. The greater tendency of German to degeminate adjacent segments (or otherwise break these segments up) can be seen in the large number of double releases in the compound condition, which occur most frequently with voiceless obstruents. This may be linked to the consonant type but may also, as mentioned above, be contingent on the morphological transparency of each individual item. While our data are not sufficient to draw any firm conclusions on this particular point, this merits further investigation.

Overall, the results from the acoustic measures, duration of closure, VD, and VOT are very similar for the fake geminates in English and German and also resemble what we find for lexical geminates in languages which do have an underlying contrast. These results also tie in with the results for word-internal geminates in the study by Oh and Redford (2012) on prefixes in English but add to them by showing that fake geminates behave like lexical geminates in compound words across a range of consonants in both English and German.

Although both Old English and Old High German contrasted singleton and geminate consonants, this distinction disappeared in the late Middle periods of English and High German. The descendants of words like Old English *bitter* “bitter,” *scilling* “shilling,” and *cunning* “†learning, skilful deceit” are now all pronounced with single medial consonants in Southern British English, as are the descendants of words like OHG *swimman* “to swim” and *sunna* “Sun” in present-day Standard High German (*schwimmen* and *Sonne*, respectively). However, it seems that although lexical geminates no longer exist in either language, native speakers still produce geminate closures when identical sequences of consonants are concatenated. This is true with regard to both derivational suffixes and compounds, independent of consonant type, although German shows greater variability in the treatment of compound-boundary adjacent segments. That is, both sounds with an audible closure and voiceless obstruents with silent closures lead to a significantly longer duration of closure. As we predicted, the sequences of identical consonants within a prosodic word, which includes both compounds and suffixed words, are realized as geminates while this does not occur in phrases.

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