The influence of accentuation and polysyllabicity on compensatory shortening in German

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Abstract

The aim of this study was to investigate the relationship between compensatory shortening and coarticulation in German tense and lax vowels in trochees and iambs and to determine whether this relationship was influenced by prosodic accentuation. Speakers produced near minimal pairs differing in vowel tensity in monosyllabic and disyllabic words (both trochees and iambs) in accented and deaccented contexts. We found significant effects of polysyllabic shortening, but only in tense vowels of nuclear-accented target words. Both stress patterns (trochaic and iambic) showed equal effects of polysyllabic shortening. Thus, while the duration of tense vowels in this study depended on accentuation and syllabicity, perhaps in order to provide perceptual cues for the listener, lax vowels were immune from lengthening and shortening phenomena. As a result, the durational difference between tense and lax vowels appears to lessen in prosodically weak contexts. The greater overlap of acoustic duration in deaccented contexts may contribute to the origin of the diachronic merger of tense and lax vowels in some languages.

Index Terms: coarticulation, speech timing, compensatory shortening, polysyllabic shortening, accentual lengthening

1. Introduction

The present study is concerned with compensatory shortening and in particular with the temporal compression of rhythmically strong syllables in polysyllabic words. Thus, the vowel in English *sleep* is longer than the same vowel in English *sleepiness* [1]. Polysyllabic shortening has been well-documented in Germanic languages such as English [2, 3, 1, 4, 5, 6], Dutch [7] and Swedish [8, 9, 10, 11, 12]. Some authors, notably [13] in a study of English, have found no evidence of polysyllabic shortening. There is also evidence that the phenomenon is limited to stress-timed languages: studies on Finnish [14] and Hungarian [15] found no indication of polysyllabic shortening, although a later study found some evidence of polysyllabic shortening in accented words in Hungarian [16].

There is evidence that a primary-stressed syllable is shortened to a greater extent by following than by preceding (word-internal) syllables: that is, anticipatory shortening has a stronger effect than backward shortening on the duration of primary-stressed syllables [17, 18, 11, 12, 19, 20, 21].

The main issue to be considered in this paper - and one that has been neglected in prior research - is the extent to which these compensatory effects interact with other influences on speech timing, in particular with prosodic accentuation and vowel tensity. In Germanic languages, a word can be accented when a pitch accent is associated with a rhythmically strong syllable in the word [22]. However, it is unclear whether the compensatory effects are manifested to the same extent in unaccented words, given that most studies have investigated this effect primarily with regard to polysyllabic shortening in (nuclear) accented syllables (see [20, 23]). A further issue to be explored is the influence of vowel tensity: it may be that polysyllabic shortening is manifested primarily in tense vowels, given that these have been shown to be more compressible than lax vowels in German [24, 25].

In summary, our aim was to test the following hypotheses concerning polysyllabic shortening. Firstly, vowel compression due to compensatory shortening would be marked in accented but scarcely in deaccented words [19, 20, 23]; and secondly, it would be in evidence to a greater extent in tense than in lax vowels [24, 26]. Thirdly, shortening should be greater in trochees than iambs, given the other findings that anticipatory shortening is more marked than backward shortening [11, 18, 19, 21].

2. Method

2.1. Participants

Twenty L1 speakers of Standard German (10 male, 10 female) were recorded with a sampling rate of 44 100 Hz in a sound-attenuated booth. Speakers had no known language, speech, voice, or reading and writing impairments. Stimuli were presented and recorded using SpeechRecorder software [27], with which the stimuli were presented to the subjects on a computer screen mounted on the inside wall of the booth. All subjects were paid for their participation.

2.2. Stimuli

In German, tense vowels are phonologically long, while lax vowels are phonologically short, for example /ˈbiːtn/ (to offer) vs. /ˈbɪtn/ (to request). As the experiment investigated the influence of two phonological vowel lengths, a target vowel was chosen that varied mostly in its quantity and not in its quality. The German vowel that differs least in quality between its tense and lax versions is the open central /a/, for example *Lamm* /lam/ (lamb) vs. *lahm* /laːm/ (lame) [24]. Thus, the chosen lax vowel was /a/ and the tense vowel /aː/.

	Monosyllables		Disyllables	
	/a/ (A/U)	**/aː/** (A/U)	**/a/** (A/U)	**/aː/** (A/U)
iambic condition	/zakt/	/zaːkt/	/fəˈzakt/	/fəˈzaːkt/
	/las/	/laːs/	/fəˈlas/	/fəˈlaːs/
trochaic condition	/takt/	/taːkt/	/ˈtaktn̩/	/ˈtaːktn̩/
	/ʃtat/	/ʃtaːt/	/ˈʃtatn̩/	/ˈʃtaːtn̩/

Table 1: The 16 target words, spoken in both accented (A) and deaccented (U) contexts (= 32 target words).

Two consonantal contexts (i.e. the rows in Table 1, which are regarded as Items for the purposes of statistical analysis) were tested for each of the conditions Syllabicity (monosyllabic vs. disyllabic), Accentuation (accented vs. deaccented), Vowel Tensity (tense vs. lax) and Stress Pattern (trochaic vs. iambic), leading to a total of 32 stimuli. Each speaker produced 5 repetitions of each stimulus, leading to a total of 160 target utterances for each speaker (15 subjects x 160 utterances = 2 400 utterances). The target words and carrier sentences were matched in number with fillers, such as *Timo wollte [filler word] sagen* (Timo wanted to say [filler word]).

The target words were embedded in phrase-medial position in the carrier sentence *Anna wollte [target word] vorlesen* (Anna wanted to read [target word] out) in order to avoid effects of phrase-final lengthening. Before each sentence appeared on the computer screen, the participants were presented with a question designed to elicit a narrow focus on the target word for the accented context and a broad focus for the deaccented context: either *WAS wollte Anna vorlesen?* (WHAT did Anna want to read out?) or *WER wollte [target word] vorlesen?* (WHO wanted to read [target word] out?). Thereafter, the stimulus was presented, with the word carrying the nuclear accent in capital letters. If subjects made a mistake, they were instructed to repeat the sentence.

2.3. Procedure

The 160 target utterances and 160 fillers were presented in randomised order. The speakers were naive as to the object of investigation and were instructed to produce the sentences as they would in everyday speech.

Five subjects were eliminated from further analysis. Two were unable to elicit the correct accentuation patterns of the stimuli, while two further subjects consistently pronounced the schwa in stimuli such as /ˈʃtaːtən/ (usually elided in running speech), which consistently led to more marked shortening of the target vowel. As the latter two subjects behaved differently from the other 18 participants, they were excluded from statistical analysis. A fifth subject misread too many of the sentences presented on the screen. The remaining 15 speakers (7 males, 8 females; mean age 27 years) were included in the analysis.

The entire corpus was automatically segmented and labelled using the Munich Automatic Segmentation System [28] and corrected manually by the first author. During this procedure several rare cases of incorrect accentuation were discovered and removed from the database. The fundamental frequency and amplitude of the remaining target utterances was calculated using the Emu Speech Database [29] in order to confirm that the speakers were able to elicit successfully the desired accentuation patterns. The f0 and amplitude of the nuclear-accented target word were consistently higher than the deaccented target word, and accented target words were longer in duration than their deaccented counterparts.

3. Results

One mixed model was calculated for each combination of stress pattern and vowel tensity (= 4 models). As the consonant durations of the target words did not remain constant but varied depending on accentuation (see e.g. [30]), measuring the vowel duration as a proportion of the syllable or syllable onset + nucleus was not a reliable option. For example, the effect of accentual lengthening on the initial /t/ in /takt/ - /taːkt/ - /ˈtaktn̩/ - /ˈtaːktn̩/ was stronger than on the syllable onsets in other conditions, thus comprising an inconsistent proportion of the target syllable duration.

For this reason, absolute vowel duration was used as the dependent variable. Accentuation and Syllabicity were treated as fixed effects, while Subjects and Items (i.e. the rows of near minimal pairs in Table 1) were treated as random effects.

All mixed models were calculated using the `lme-4` package in `R` [31].

3.1. Trochees

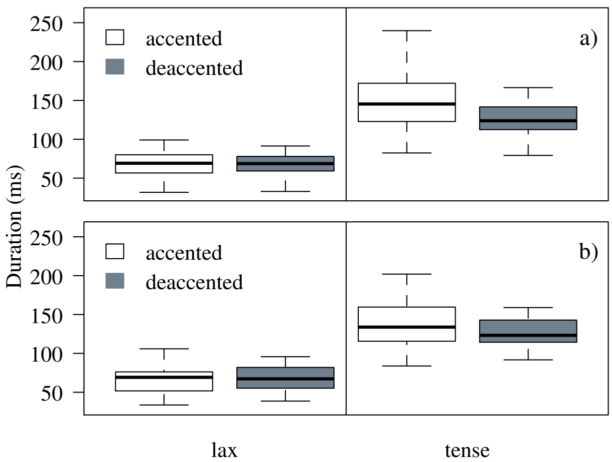

Figure 1: Trochaic condition: a) Monosyllables; b) Disyllables. Duration (ms) of the target vowel is displayed as a function of vowel tensity.

Figure 1 reflects the overall results for the trochaic condition, suggesting that lax vowels could not be further compressed by deaccentuation or polysyllabic shortening [24], while tense vowels were subject to compensatory shortening in both conditions.

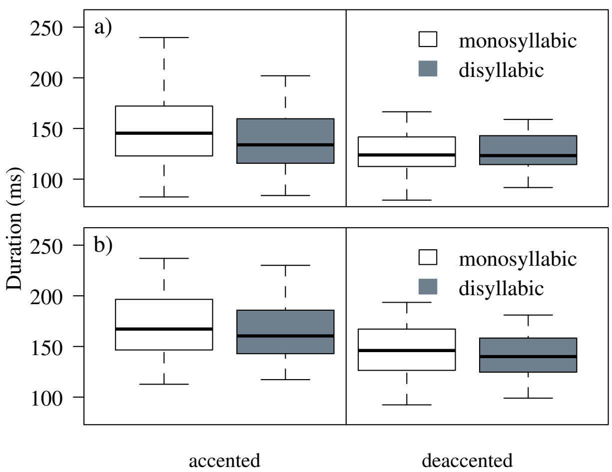

Figure 2: Tense vowels: a) Trochees; b) Iambs. Duration (ms) of the target vowel is displayed as a function of accentuation. Monosyllabic stimuli are white; disyllabic stimuli are grey.

Neither Accentuation nor Syllabicity had any significant effect on the duration of lax vowels in the stressed syllable of trochees, and there were no significant interactions between factors. This result is in accordance with the findings of [24] who found that deaccentuation does not cause temporal shortening of lax vowels.

For tense vowels, the findings appear to support the earlier findings of [23] that polysyllabic shortening primarily affects accented words. Main effects of Accentuation ($\chi^2[2] = 175.3; p < .001$) and Syllabicity ($\chi^2[2] = 6.8; p < .01$) indicated that deaccentuation of the target word and the addition of a syllable to the right of the primary-stressed syllable led to significant compensatory shortening of the target vowel. Figure 2a) shows the significant effects of Accentuation (left vs. right) and Syllabicity (white vs. grey) on the duration of the tense target vowels. A significant interaction ($\chi^2[1] = 175.3; p < .001$) rendered pairwise comparisons necessary. Post-hoc Tukey tests confirmed the highly significant shortening effects of deaccentuation and polysyllabic shortening in all combinations of Accentuation and Syllabicity ($p < .001$) with the exception of polysyllabic shortening of the deaccented condition ($p = .7$). That is, in /ˈtaːktn̩/ und /ˈʃtaːtn̩/ (accented) the target vowel was significantly shorter than that in /taːkt/ und /ʃtaːt/ (accented), but there was no significant difference between the target vowels in the monosyllables and disyllables of the deaccented condition.

3.2. Iambs

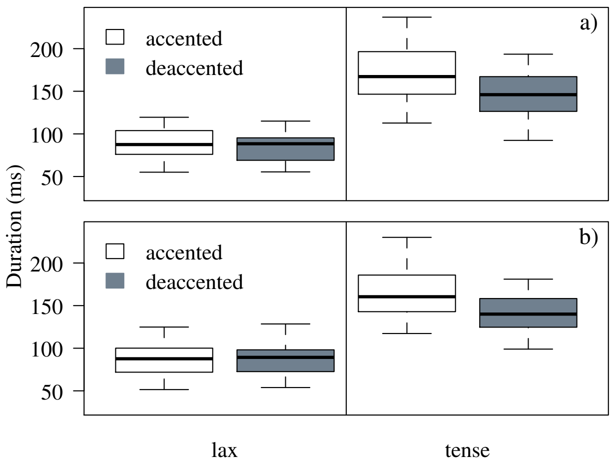

Figure 3: Iambic condition: a) Monosyllables; b) Disyllables. Duration (ms) of the target vowel is displayed as a function of vowel tensity.

Figure 3 reflects all vowels of the iambic condition, suggesting that lax vowels could not be further compressed by deaccentuation or polysyllabic shortening, while tense vowels were subject to compensatory shortening in both conditions.

As predicted, neither Accentuation nor Syllabicity had any significant effect on the duration of lax vowels in the stressed syllables of iambs, and again there were no significant interactions. Once again, this supports the results of [24] that deaccentuation does not cause temporal shortening of lax vowels, nor does it appear that lax vowels in German are subject to polysyllabic shortening.

Figure 2b) shows the significant effects of Accentuation (left vs. right) and Syllabicity (white vs. grey) on the duration of the tense target vowels. Main effects of Accentuation ($\chi^2[2] = 287.2; p < .001$) and Syllabicity ($\chi^2[2] = 9.9; p < .01$) indicated that deaccentuation of the target word and the addition of a syllable to the left of the primary-stressed syllable led to highly significant compensatory shortening of the target vowel. No significant interactions were detected.

However, in order to test whether polysyllabic shortening had a weaker effect on deaccented words, as hypothesised by [32, 19, 23], we carried out Post-hoc Tukey tests. These confirmed the highly significant effect of Accentuation on the duration of both monosyllabic and disyllabic stimuli ($p < .001$). Syllabicity had a shortening effect on accented stimuli ($p < .05$), but not on deaccented stimuli. Thus, deaccented target vowels in iambs were not subject to polysyllabic shortening. That is, in /fəˈzaːkt/ and /fəˈlaːs/ (accented) the target vowel was significantly shorter than that in /zaːkt/ and /laːs/ (accented), but there was no significant difference between the target vowels in the monosyllables and disyllables of the deaccented condition. This finding again supports our hypothesis based on the earlier findings of [32, 19, 23] that polysyllabic shortening primarily affects accented words.

3.3. Trochees vs. Iambs

While this is not the first study to find evidence of backward shortening (see [7, 12]), this result underlines the need to investigate whether trochees are shortened more than iambs. A final mixed model compared the two stress patterns. The data analysis was restricted to accented tense vowels only, as the above results indicate that only these vowels were subject to shortening. The dependent variable was the absolute duration of the target vowel in the disyllabic condition as a proportion of the target vowel in the monosyllabic condition (means calculated separately for each subject). We used proportional durations rather than absolute durations in order to examine the total effect of shortening on each condition. For example, an absolute durational difference of 50ms for both stress patterns fails to reveal whether 50ms is a larger proportion of the target vowel in one stress pattern than in the other. Stress Pattern was treated as a fixed effect, while Subjects were treated as random effects (a pretest showed no benefit of including Items as random effects).

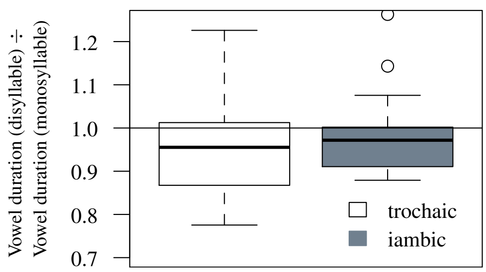

Figure 4: Trochaic stress pattern (white) vs. Iambic stress pattern (grey). The y-axis shows the duration of the target vowel in the disyllabic condition as a proportion of the duration of the target vowel in the monosyllabic condition. The lower the ratio, the stronger the shortening. Only accented tense vowels were examined.

Figure 4 shows the effect of Stress Pattern (trochaic vs. iambic) on the degree of polysyllabic shortening. The lower the ratio on the y-axis, the stronger the effect of polysyllabic shortening on the target vowel. There was no evidence that the amount of polysyllabic shortening differs depending on Stress

Pattern. Thus, contrary to our hypothesis and previous findings [17, 18, 11, 12, 19, 20, 21], the effects of anticipatory vs. backward shortening appear to be symmetrical in this study.

4. Discussion

We predicted stronger compensatory shortening of nuclear-accented words and of tense vowels. In line with these two hypotheses, we found no significant effects of accentuation or syllabicity on the duration of lax vowels, but we found significant effects of both factors on the duration of tense vowels. Similarly, polysyllabic shortening was restricted to nuclear-accented words only.

Thirdly, we tested the strength of the two stress patterns. Compensatory shortening was expected to be stronger in trochees (anticipatory shortening) than in iambs (backward shortening). However, we found no significant effect of stress pattern on the degree of polysyllabic shortening.

4.1. Stress Adjacency Effect

One phenomenon that was not considered during the planning of this experiment was the Stress Adjacency Effect [33]. According to this theory, the duration of a syllable with a full vowel is longer if the following syllable also contains a full vowel rather than a reduced vowel. This phenomenon could have had an effect on the present study, as the word following the target word in the carrier sentence, *vorlesen*, begins with a primary-stressed full vowel. This vowel may thus have blocked any possible shortening effects on all stimuli of the iambic condition (which contained a full vowel in the last syllable) as well as the monosyllabic stimuli of the trochaic condition.

If this were the case, however, we should have found an (increased) effect of polysyllabic shortening on the trochees, but not on the iambs. As this was not the case, we can rule out any influence of the Stress Adjacency Effect on our data. Nevertheless, future studies should take care when choosing carrier sentences to eliminate any such effect.

4.2. Lengthening vs. Shortening

Some authors hypothesise that any true polysyllabic shortening would affect both trochaic and iambic stress patterns equally [19, 23], but that Germanic languages have so far shown mostly asymmetrical effects of polysyllabic shortening. [23] predict that polysyllabic shortening is no more than an artefact of various lengthening effects triggered by the rhythm of stress-timed languages, and any asymmetrical effects of stress pattern would "[weaken] the status of polysyllabic shortening as a speech timing mechanism with general applicability" [23, p461]. This prediction is strengthened by the lack of evidence for polysyllabic shortening in non-stress-timed languages such as Finnish and Hungarian. Shortening as a mere side effect of combined lengthening effects could be triggered by the Stress Adjacency Effect [33], word and phrase-final lengthening [34, 35, 36, 37], word-initial lengthening [34, 5, 37] and accentual lengthening [32, 38, 30, 20].

The results of the present study indicate that accentual lengthening is indeed a prerequisite for the occurrence of polysyllabic shortening (which only ever occurred in the accented condition). However, in this study we found no influence of stress pattern on the degree of shortening (see Figure 4), which would appear to rule out any artefactual effects based on word or phrase boundaries. This could also be tested in future experiments by excluding word-initial and word-final lengthening effects by comparing monosyllabic with trisyllabic stimuli in which the primary-stressed syllable is the second syllable.

At least in the present study, the effect of compensatory shortening cannot be explained as an artefact of combined boundary effects.

4.3. Incompressibility

While absolute inherent vowel durations are not easily calculated, the idea of a minimal inherent vowel duration that can be lengthened depending on its context would be an attractive way to explain compensatory shortening phenomena. The concept of incompressibility was first introduced by [4, 5]. It expresses the minimal possible time needed to carry out the articulatory gestures of a certain vowel. Temporal increments could be added to the vowel as perceptual cues to factors such as vowel tensity, stress or accent, position within a word or boundary, or the voicing or manner of articulation of the following consonant. Polysyllabic shortening would involve the removal of such an increment from the monosyllabic condition.

The results of this experiment and those of [24] for German and [39, 1] for English show evidence that short vowels cannot, or can scarcely, be shortened. Deaccented target words were also immune from shortening in this experiment and others [19, 20, 23]. Some experiments on compensatory shortening found non-linear shortening effects: the extent of shortening is greater in monosyllabic compared with disyllabic words than in disyllabic compared with trisyllabic words [12, 18]. These findings provide evidence of an inherent minimal duration of each vowel that acts as the starting point for any temporal lengthening processes.

Thus, consistent with [20, 23], it may be that there are lengthening (rather than shortening) effects, and that lax vowels provide the minimum base durations for these.

5. Conclusions

This study found that the duration of tense primary-stressed vowels in nuclear-accented words was shorter in polysyllabic compared with monosyllabic words in both trochees and iambs.

While the duration of tense vowels in this study depended on accentuation and syllabicity, perhaps in order to provide perceptual cues for the listener, lax vowels were immune from lengthening and shortening phenomena. As a result, the durational difference between tense and lax vowels appears to lessen in prosodically weak contexts (cf. Figures 1 and 3), although this needs to be tested in further experiments. Data on German speakers' perception such as that gathered by [21] for English is necessary to establish the degree of compensation for this coarticulation in speech perception. If perception of coarticulation is not matched with its production, prosodically weak contexts could be a breeding ground for sound change [40, 41] such as the diachronic loss of contrastive vowel length (already documented in some varieties of German, see [42]).

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