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Phonetic content and phonological structure affect pre-boundary lengthening in German

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Abstract

This paper reports on a production experiment investigating the domain of pre-boundary lengthening (PBL) in German. Prior studies found that PBL is initiated on the last main stress syllable before the phrase boundary and gradually increases up to the end of the phrase. Our results show that the initiation of PBL also depends on the phonetic content: An analysis of name pairs only differing as to the presence of a final coda consonant (e.g. *Ramona* vs. *Ramonas*) revealed that an additional segment leads to a later initiation of PBL. Furthermore, the results show that the amount of PBL largely increases on the final rime independent of its internal structure, which attests a structure-based effect on the distribution of lengthening within the PBL domain. We account for our findings by means of a model that incorporates the main stress syllable as an anchor for the PBL domain, but allows PBL to expand to the left if the amount of following material is limited. The effects found for German in this study resemble some of the observations recently made for Japanese, which suggests that they might be universal tendencies.

Index Terms: prosodic phrasing, pre-boundary lengthening, lengthening domain, German

1. Introduction

One of the major correlates of prosodic phrasing is the lengthening of material immediately preceding the phrase boundary. This effect, referred to as pre-boundary lengthening (PBL), has been attested for German as a stable correlate of boundary production (e.g., [1]) and a reliable cue for boundary perception (e.g., [1,2,3]). The present study addresses two aspects with regard to the production of PBL in German that are not well understood: First, it remains unclear what stretch of speech, or *domain*, preceding the boundary is affected by lengthening. This aspect is investigated with regard to the phonetic content of the phrase-final word. Second, this study explores how the amount of lengthening is distributed within the PBL domain, testing for a potential influence of the structure of the phrase-final syllable.

Most approaches to the specification of the PBL domain refer either to phonological structure or to phonetic content as the crucial factor for the initiation of PBL. Structure-based models assume that the domain is defined by a specific phonological constituent, such as a syllable or rime, in the phrase-final word. For example, it has been found for German that the PBL domain ranges from the nuclear vowel of the last main stress syllable to the end of the prosodic phrase [4]. This pattern also occurs in other stress languages, such as British English [5], Dutch [6], Estonian [7], Finnish [8], Greek [9], and Hebrew [10]. As for German, however, instances of PBL have also been observed on the segment immediately preceding the main stress syllable [11]. This variation might be due to a content-based effect.

Content-based models assume that the PBL domain varies depending on the phonetic content of the phrase-final material. The most prevalent model in this framework assumes a lengthening gesture of fixed duration that overlaps with the final word (e.g., [12,13,14]). Under this view, the point of PBL initiation is not tied to some structural element, but varies depending on the type and number of given segments. Following [12], this is due to an overlapping prosodic gesture, referred to as Pi-gesture, which controls the temporal dynamics of a series of articulatory gestures, but does not result in an articulatory constellation itself. This assumption is henceforth referred to as Overlap hypothesis [15].

Furthermore, some languages involve structure-based as well as content-based aspects. Such a hybrid model was proposed for Dutch [6], which takes the vowel of the main stress syllable as the default initiation point (a structure-based anchor). However, in case the PBL domain includes a segment that is not expandable, such as a Schwa, the initiation of PBL occurs on preceding material (a content-based effect). More recently, [16] showed that in Japanese PBL is initiated on the vowel of the penultimate syllable in a disyllabic word unless both syllables comprise a coda consonant. If the word consists of two CVN syllables, the initiation of PBL shifts to the coda consonant of the penultimate syllable (a content-based effect). At the same time, [16] observed that PBL in Japanese is affected by structural aspects such as the presence of a lexical pitch accent, which suppresses PBL in the word-final rime.

As for the temporal dynamics, many studies identified a pattern of progressive lengthening within the PBL domain (e.g., [17] for Dutch, [14] for American English, [8] for Finnish, [4,11] for German, [16] for Japanese). That is, the amount of PBL gradually increases towards the end of the prosodic phrase so that the largest amount occurs on the final segment. This mechanism operates independent of the prosodic structure and interacts with the expandability potential of the given segments. For example, it has been found that word-final fricatives involve a larger amount of lengthening than word-final oral stops in Hebrew [10] and Dutch [16]. Furthermore, [15] attested a weak effect for progressive lengthening in American English: Elements occurring later in the phrase-final word tend to involve a relatively larger amount of PBL, but the components within these elements may involve a decrease or interruption of PBL.

Some studies found that PBL is particularly strong on the final rime (e.g., [15] for American English, [16] for Japanese). In Japanese, the amount of PBL in the final rime of an open syllable (CV) appears to be comparable to the amount in the final rime of a closed syllable (CVC) [16]. This suggests that the prosodic structure of the phrase-final word may not only be involved in the initiation of PBL, but also affect the relative amount of lengthening within the PBL domain.

In the following, we report on a production experiment that investigated the PBL domain in German. Based on the results, we argue that PBL is best accounted for in the framework of a hybrid model that incorporates phonological structure and pho-

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Table 1: *Example item comprising 'Ramona' as the target word without suffix (CV.CV.CV) and with suffix (CV.CV.CVC)*

Syllable structure	Position in prosodic phrase	Sentence
CV.CV.CV	medial	Ich werde **Karolin oder Ramona und Peter** einladen.
	final	Ich werde **Karolin oder Ramona und Peter** einladen.
		'I will invite Karolin or Ramona and Peter.'
CV.CV.CVC	medial	Ich werde **Karolins oder Ramonas und Peters Freunde** einladen.
	final	Ich werde **Karolins oder Ramonas und Peters Freunde** einladen.
		'I will invite Karolin's or Ramona's and Peter's friends.'

netic content in order to capture the specification of the domain and the relative lengthening patterns within the domain.

2. Research questions and hypotheses

The present study addresses the following questions with regard to the PBL domain in German:

2.1. Does the phonetic content (in terms of number of segments) of the phrase-final word affect the initiation of PBL?

Attesting an effect of phonetic content on the initiation of PBL would support the Overlap hypothesis and suggest that the PBL domain is not exclusively defined by phonological structure. In the present study, the Overlap hypothesis is supported if the presence of additional material at the end of the phrase-final word leads to a later initiation of PBL. More specifically, we predict that the addition of a consonant to the coda of the word-final syllable shifts the initiation point further to the right.

2.2. Does the relative amount of lengthening consistently increase towards the end of the phrase-final word?

Given the observations from prior studies, we expect that German involves a pattern of progressive lengthening. We seek to explore if the gradual increase is consistent throughout the PBL domain. Finding an intermediate decrease or interruption of PBL would suggest that German involves a weak form of progressive lengthening.

2.3. Does the phonological structure of the phrase-final word affect the relative amount of lengthening?

This question addresses the possibility that there is a specific phonological constituent that triggers a considerable increase of lengthening. Given the findings from other languages, we hypothesize that the word-final rime serves as such a trigger, which we will refer to as Final Rime hypothesis. This hypothesis is supported if a considerably larger amount of lengthening is found for the segments in the final rime independent of the rime-internal structure.

3. Methods

3.1. Stimuli

The production experiment controlled for the number of segments in the final rime and the presence of a following prosodic boundary. We employed six target words, which were trisyllabic proper names with CV.CV.CV structure and penultimate word stress (*Ramona*, *Simona*, *Marina*, *Rosina*, *Verena*, *Selina*). These were elicited under two conditions affecting the rime of the final syllable: In one condition, they were in accusative case and retained their CV.CV.CV structure; in the other condition, they were in genitive case and involved CV.CV.CVC structure due to the case marking suffix -s, realized as [s], added as a coda consonant to the final syllable (e.g. *Ramonas*). Moreover, the stimuli contained a different type of target words, comprising antepenultimate word stress, which is not reported on here.

The realization of a prosodic boundary after the target words was elicited by structurally ambiguous lists of the type [A or B and C], where A, B, and C were proper names. Such lists can be interpreted as comprising a left-branching structure [[A or B] and [C]] or a right-branching structure [[A] or [B and C]]. The target words were exclusively in position B. Prior studies (e.g. [1,15,18]) showed that the ambiguity is resolved by means of a prosodic boundary after B in the left-branching case, such that B is in phrase-final position, and after A in the right-branching case, such that B is in phrase-medial position. The lists were embedded in a carrier sentence, which was preceded by a short context story. Each list was elicited twice, once with the left-branching structure, which triggers a prosodic boundary after the target word, and once with the right-branching structure, which does not trigger a prosodic boundary after the target word. We indicated the branching structure by setting the lists in bold and underlining the contained constituents. An example item is given in Table 1. Furthermore, in order to facilitate the interpretation, pictures showing the respective grouping of persons were presented below the sentences.

3.2. Design and procedure

We employed twelve items involving the conditions summarized in Table 1 in a within-subjects design. Each of the six target words occurred in two items. The target expressions were pseudo-randomized and interspersed with filler expressions. The subjects were familiarized with the type of sentences and instructed to resolve the ambiguity when producing the sentences. Furthermore, they were informed that the experimenter would listen to their productions on-line and had to decide which of the two interpretations of the sentences was expressed (following the method in [1]). This was supposed to make the subjects realize the disambiguating prosodic cues more reliably (see, e.g., [19,20] for this effect).

During the recordings, the subject and the experimenter were sitting at a table separated by a shoulder-high screen. The stimuli were presented to the subject one by one on a display screen. The subject first read the stimulus and then produced the target sentence. For each production, the experimenter saw the sentence twice on a printed list, marked once with the left-branching and once with the right-branching structure. The experimenter listened to the subject's production, decided which structure was expressed, and checked a box next to the sentence on the list. The subject did not see the experimenter's decision and no feedback was given. The experimenter identified the correct structure in 98.3 percent of cases across subjects and con-

ditions. We recorded 24 subjects (mono, 16 bit, 44.1 kHz), who were all native speakers of German aged between 18 and 25 years. The recording sessions took place in a sound-attenuated booth and lasted about 45 minutes.

3.3. Analysis

So far, we analyzed the data for the target words with penultimate stress from twelve out of the 24 subjects. Following the guidelines for acoustic speech segmentation suggested in [21], we manually annotated the boundaries of all segments in the target words based on spectrographic and waveform information using the acoustics analysis software Praat [22]. Subsequently, the duration values of the segments were extracted by a script.

Below, we present our first analysis, in which the data for the target words without suffix (CV.CV.CV) and with suffix (CV.CV.CV) were analyzed separately. Linear mixed effects models accounting for DURATION as a function of BOUNDARY were fitted to the data of each segment using the software environment R [23] and the lme4 package [24]. Random intercepts and slopes were included for SUBJECT and random intercepts for ITEM. In case of non-convergence, the random slopes were removed, but all models comprised intercepts for SUBJECT and ITEM in the random structure. The models were tested against reduced models without BOUNDARY as a fixed factor by means of likelihood ratio tests (LRTs).

4. Results

4.1. The PBL domain

Figure 1 presents the data for the segments of the target words without suffix (CV.CV.CV) across subjects. As indicated above the plots, the LRTs yielded a significant effect ($p<.001$) for the models fitted to the data of the last four segments in the target words (C2, V2, C3, V3). The boxplots indicate that the duration of these segments was longer in phrase-final than in phrase-medial position. Thus, the PBL domain reaches from the onset of the penultimate syllable to the end of the word (CV.CV).

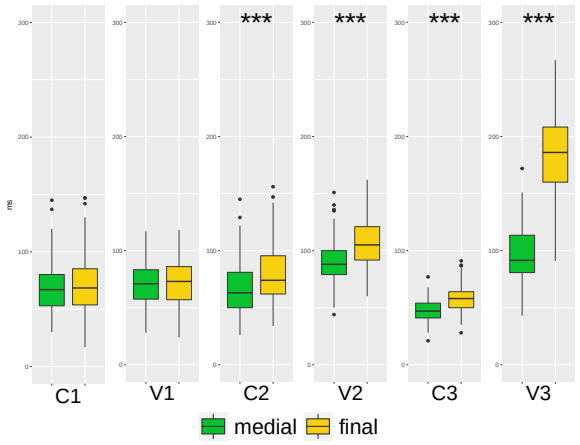

Figure 1: *Duration of the segments of the target words without sufffix, comprising CV.CV.CV structure (e.g. Ramona), across subjects (n=144).*

Figure 2 presents the data for the segments of the target words with suffix (CV.CV.CVC) across subjects. Again, the LRTs yielded a significant effect ($p<.001$) for the models fitted to the data of last four segments in the target words (V2, C3, V3, C4) and the boxplots indicate that the duration of these segments was longer in phrase-final than in phrase-medial position. Thus, the PBL domain reaches from the nucleus of the penultimate syllable to the end of the word (V.CVC).

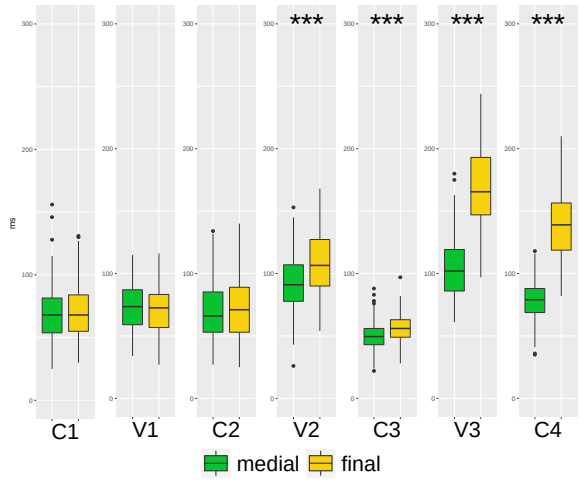

Figure 2: *Duration of the segments of the target words with suffix, comprising CV.CV.CVC structure (e.g. Ramonas), across subjects (n=144).*

4.2. The amount of lengthening

Figure 3 shows the percent increase in phrase-final position for each segment in the target words with and without suffix based on the mean segment duration across subjects. In phrase-final position, the target words without suffix (CV.CV.CV) involve a mean increase of 19.3 percent on the first element of the PBL domain (C2) followed by a mean increase of 17.4 percent on the second element (V2) and a mean increase of 21.1 percent on the third element (C3). In the final segment (V3), the mean increase rises to 92.2 percent. As for the target words with suffix (CV.CV.CVC), the mean increase is 15.5 percent on the first element (V2) and 11.7 percent on the second element (C3) of the PBL domain. After that, it rises to 65 percent on the prefinal segment (V3) and 76.8 percent on the final segment (C4).

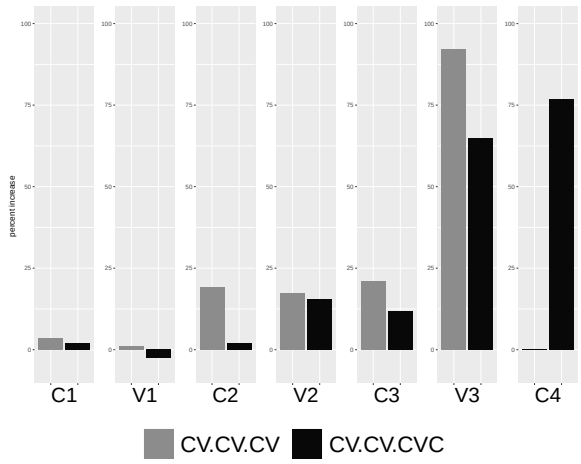

Figure 3: *Percent increase of the mean segment duration in phrase-final position across subjects (n=144).*

Thus, the PBL domain in both conditions comprises a comparatively small amount of lengthening on the segments preceding the final rime followed by an abrupt increase on the last nuclear vowel. This increase is larger when the vowel is the final segment than when a coda consonant follows. The amount of PBL further increases on the final coda consonant so that the largest amount occurs on the final segment in both conditions.

5. Discussion and conclusions

The PBL domain comprised the last four segments of the target words independent of the structure of the final rime. When the suffix was absent, the domain included the ultimate and penultimate syllable (CV.CV) and when it was present the domain reached from the vowel of the penultimate syllable to the end of the word (V.CVC). Thus, the addition of a coda consonant to the final rime shifted the initiation of PBL to the following segment. This effect supports the Overlap hypothesis, suggesting that the phonetic content of the phrase-final material contributes to the specification of the PBL domain. In terms of the Pi-gesture model [12], the effect can be construed as resulting from a prosodic gesture that yokes the articulatory gestures responsible for the last four segments in the phrase-final word.

This finding does however not exclude the possibility that the main stress syllable serves as an anchor for the PBL domain. In fact, the initiation point of PBL was located in the stressed syllable in both conditions: If the suffix was absent, PBL was initiated on the onset of the stressed syllable, and if it was present, PBL was initiated on the vowel of the stressed syllable. The latter is in line with prior findings on PBL in German (e.g. [4]). Given the support for the Overlap hypothesis found in this study and the observation that the main stress syllable aligns with the PBL domain in German and other stress languages, we hypothesize that the nuclear vowel of the main stress syllable serves as an anchor for the PBL domain, but the domain expands to the left if the amount of material between the vowel and the upcoming phrase-boundary is limited.

Our investigation on the amount of PBL revealed a weak effect of progressive lengthening: The material in the word-final rime showed a larger amount of PBL than the preceding material in the PBL domain. If the final rime was complex, the amount increased from the nuclear vowel to the coda consonant so that the largest amount always occurred on the final segment. However, the segments preceding the final rime did not show a pattern of consistent increase, but involved a slight decrease on one of the involved segments in both conditions. Thus, as found for American English [15], there is a global tendency of progressive lengthening, but PBL does not increase consistently throughout the domain. However, unlike in American English, we did not find an intermediate interruption of PBL.

As for an influence of phonological structure, we found that the amount of lengthening is considerably larger in the final rime than in the preceding part of the PBL domain. This distribution supports the Final Rime hypothesis, as it occurred independent of the internal structure of the final rime. Thus, the prosodic structure of the phrase-final word contributes to the overall distribution of the amount of lengthening within the PBL domain. This is in line with the PBL patterns observed in other languages, such as American English [15] and Japanese [16]. The effect of PBL boosting in the final rime can however not account for all instances of progressive lengthening we observed. Given that progressive lengthening also occurred within the final rime suggests that there is an independent mechanism that gradually increases the amount of lengthening while approaching the phrase boundary.

Altogether, this study proposed a hybrid model to account for the patterns of PBL in German. The model comprises structure-based as well as content-based aspects that regulate both the specification of the PBL domain and the lengthening patterns within the domain. Regarding the phonological structure, the model assumes that the main stress syllable serves as an anchor for the PBL domain and the final rime as a booster for the amount of PBL. Furthermore, the model stipulates that the initiation of PBL is shifted to earlier material if the phonetic content is limited. Finally, there is a structure-independent progressive lengthening effect that operates within the final rime, but is not consistently applied to earlier material.

The assumption that the main stress syllable serves as an anchor for PBL initiation is adopted from prior studies. The data presented here are compatible with this assumption, but do not provide independent evidence. If this assumption holds, it is expected that the PBL domain of words with antepenultimate main word stress begins on the nuclear vowel of the antepenultimate syllable and may thus be longer than in words with penultimate stress. Furthermore, the model predicts that a phrase-final word with ultimate main word stress involves PBL on material that precedes the main stress syllable (as the limited amount of content would lead to a leftwards expansion of the PBL domain). Attesting these patterns would provide further support for the present account.

From a cross-linguistic perspective, it seems plausible that the phonetic content as a predictor for the PBL domain and the final rime as a predictor for the relative amount of lengthening are universally relevant. Both aspects were recently found to apply to Japanese [16] in a similar way as they were attested for German in the present study. This suggests that these aspects operate independent of the prosodic system of a language. Further research on languages with different prosodic systems, such as tone languages or phrase-based languages, is needed in order to explore this possibility. Similarly, a connection between positions of prosodic prominence and the PBL domain might hold across languages.

Further research is also needed with regard to the perceptual relevance of the PBL domain and the distribution of lengthening within the domain. In order to test in which way these aspects contribute to the perception of a prosodic boundary, it is necessary to understand how they apply in speech production in the given language (see also [15]). For example, in order to test if PBL must occur within the designated domain or may as well be located on other material near the potential boundary location, we need to understand which factors are involved in the specification of the domain. The present study provided insights for German that are essential for such investigations. Our results also suggest that lengthening on the final rime provides the strongest cue for the perception of a prosodic boundary by means of PBL. Yet, it remains unclear if the lengthening difference on the preceding material is perceptually distinguishable. Future research should test if listeners are sensitive to a certain amount of lengthening in general or if they take the durational pattern on the final rime as the means for boundary detection.

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