Disentangling lexical, morphological, syntactic and semantic influences on German prominence – Evidence from a production study

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Abstract

The aim of this paper is to examine effects on syllable prominence exerted by word and phrase boundaries, lexical stress, and sentence focus, and by the interactions between these factors. In a production study, German verb prefixes potentially forming prosodic minimal word pairs were systematically placed in a set of different contexts. Acoustic analyses showed a consistent effect of lexical stress on syllable prominence in both focused and unfocused sentence positions. When the verb was in sentence focus, even unstressed syllables in bisyllabic prefixes changed as a function of lexical stress. Varying sentence stress only had an effect on syllables in lexically stressed prefixes. While no effect of word boundary was found, unbound verb particles preceding phrase boundaries received the highest prominence values. Syllables in lexically stressed prefixes showed greater acoustic similarity with these unbound particles than did syllables in lexically unstressed prefixes.

Index Terms: syllables, prominence, duration, stress

1. Introduction

Syllables are given varying degrees of prominence in spoken language either to mark the lexical stress within a word or to highlight words within an utterance which are important or give new information [1, 2]. This emphasis can be realized acoustically by different means, e.g. duration, fundamental frequency, or degree of coarticulation [3]. Many studies on stress and coarticulation do not differentiate between word and sentence stress, either focusing on sentence stress only or varying word stress within utterances of single words (e.g. [4, 5]). There is evidence, however, that word stress is also realized in non-accented sentence positions and that the effect of sentence stress is not limited to the lexically stressed syllable [6, 7]. In the experiment described here, subjects were asked to read aloud German sentences containing prosodic minimal pairs. Recordings were analyzed acoustically in order to investigate the effects and interactions of word and sentence stress.

In German complex verbs, lexical stress can either be shifted to the verb prefix or left on the verb stem, resulting in minimal pairs with different meanings. For example, if in the German word "umfahren" [ʔʊm.faːɐ̯ən] the lexical stress is on the prefix [ʔʊm], the word means 'to run over something with a vehicle', but if the stress is on the verb stem it means 'to drive around or bypass something'. These contrasts are mainly realized in infinite forms of such verbs. In most other syntactic constructions, stressed prefixes are split off and placed at the end of the phrase, while unstressed prefixes remain part of the verb. Furthermore, these prefixes can also appear in the form of homophonous function words, mainly prepositions or conjunctions. The prefix "um", for instance, can be a preposition with the meaning 'around' or can belong to the word pair "um...zu", meaning 'in order to'.

Because of their characteristics, such verb prefixes can be used to examine various factors which could have an influence on the realization of stress. The way carrier sentences are formulated can influence the amount of emphasis subjects place on the verb in question, making it possible to investigate how word stress is realized across varying levels of sentence stress. Moreover, the effects of word and phrase boundary can be analyzed by comparing the bound and unbound prefixes as well as homophonous function words.

2. Methods

2.1. Material

The experiment investigates the acoustic realization of the four German prefixes "um" [ʔʊm], "unter" [ˈʔʊn.tɐ], "über" [ˈʔyː.bɐ], and "durch" [dʊʁç]. Eight verbs featuring these prefixes and forming prosodic minimal pairs were chosen. For each verb, a paradigm of 7 carrier sentences was constructed in order to evoke differences in lexical stress, sentence stress, and boundedness of the prefixes. In total, 56 sentences were created.

It was crucial for the experiment that sentences were constructed in a way that allowed subjects to clearly distinguish between the two possible verb meanings. To facilitate the disambiguation of sentence content, pictures were created to illustrate each sentence, using the text-to-

Table 1: *Structure of carrier sentences (mb = morpheme boundary, pb = phrase boundary, wb = word boundary). See text for details.*

number	lexical stress	sentence stress	following boundary	context
1	yes	yes	mb	A_B
2	yes	no	mb	A_B
3	no	yes	mb	A_B
4	no	no	mb	A_B
5	-	-	pb	A_%
6	no	yes	mb	C_B
7	-	-	wb	C_B

scene conversion program WordsEye [8]. The test items were mixed with 48 similarly illustrated filler sentences and put into a quasi-random order, ensuring that there were no sequences of stimuli belonging to the same verb.

The paradigm of sentence conditions is summarized in Table 1. In the first 4 sentences for each verb, the bound prefix is placed under different word and sentence stress conditions. Sentences 1 and 2 suggest the meaning conveyed by the verb when stressed on the prefix, whereas sentences 3 and 4 convey the sense when lexical stress is on the verb stem. To manipulate sentence stress, sentences 1 and 3 are given a broad focus, allowing the verb to be accented, while sentences 2 and 4 are formulated so as to shift sentence stress away from the verb. The phonetic context surrounding the prefix is held constant at least until the next vowel in sentences 1–4 (context A_B).

Sentences 5–7 are designed to compare bound and unbound particles. Sentence 5 contains the finite, split version of the prefix-stressed verb, with the unbound prefix appearing in sentence-final position. To allow for a comparison with the stimuli described above, the half syllable preceding the unbound prefix is held the same as in sentences 1–4 (context A_%). In carrier sentences 6 and 7, a lexically unstressed bound prefix (6) is contrasted with a homophonous preposition or conjunction in a similar phonetic context (7). The half syllables preceding and following the particle in question are kept the same for both sentences (context C_B).

2.2. Procedure

The experiment took place in an audio studio at Bielefeld University. The illustrated sentences were presented to the subjects on a computer screen one at a time, always in the same quasi-random order. Subjects were asked to look at each picture and the accompanying sentence, understand the connection between the two, and then read the sentence aloud, using their natural speaking style. They were able to progress from one sentence to the next in a self-paced manner. When they noticed mistakes they made while speaking, subjects repeated the sentence in question. 30 native German subjects from the Bielefeld University community participated in the experiment.

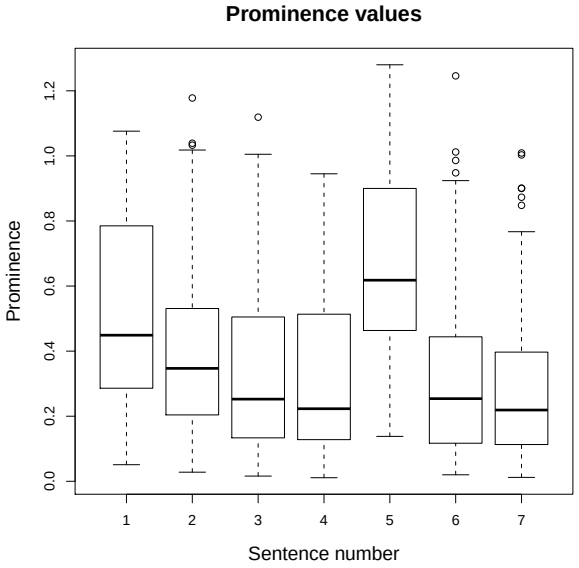

Figure 1: *Syllable prominence by sentence condition.*

3. Results

The results presented here are based on data from 10 subjects (6 female, 4 male) analyzed to date. As the 4 prefixes comprising 6 syllables ([ʔʊm], [ʔʊn], [tɐ], [ʔyː], [bɐ] and [dʊʁç]) were examined in 2 words and 7 sentences each, a total of 840 syllable items was collected. Sentences which contained slips of the tongue or had to be reread were discarded, leaving 781 syllable items for analysis.

3.1. Syllable prominence and duration

A prominence tagger was used to automatically analyze relative syllable prominence on the basis of duration, pitch movement, intensity, and spectral emphasis of syllable nuclei [9]. The context taken into consideration by the tagger consisted only of the verb prefixes themselves and the syllables preceeding and following them (if any). If the vowel preceding the prefix was strongly reduced or elided, the syllable before that vowel was annotated instead. In addition, syllable durations were calculated. Statistical analyses were performed in R [10].

Figure 1 gives an overview of the prefix syllable prominences in each sentence condition. Although there is considerable overlap, syllables in lexically stressed prefixes (sentence types 1 and 2) tend to be more prominent than their unstressed counterparts (types 3 and 4). Within these groups, there seems to be a small effect of sentence stress on syllable prominence. Sentences of type

Table 2: *Wilcoxon tests for prominence differences between syllables of different sentence conditions (matched for speaker and word; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$).*

syllable	1 vs. 3	2 vs. 4	1 vs. 2
all	$V = 4669$ ****	$V = 4037$ ***	$V = 4241$ ***
[ʔʊm]	$V = 153$ ****	$V = 187$ ****	$V = 93$
[ʔʊn]	$V = 118$	$V = 132$ *	$V = 112$
[tɐ]	$V = 138$ **	$V = 141$ *	$V = 88$
[ʔyː]	$V = 161$ ***	$V = 147$ **	$V = 139$ *
[bɐ]	$V = 132$ *	$V = 52$	$V = 154$ **
[dʊʁç]	$V = 119$ *	$V = 57$	$V = 135$ ****

Table 3: *Wilcoxon tests for duration differences between syllables of different sentence conditions (matched for speaker and word; *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$).*

syllable	1 vs. 3	2 vs. 4	1 vs. 2
all	$V = 5196$	$V = 5054$	$V = 4148$
[ʔʊm]	$V = 144$ ***	$V = 175$ ***	$V = 126$
[ʔʊn]	$V = 144$ ***	$V = 150$ **	$V = 138$ **
[tɐ]	$V = 143$ ***	$V = 153$ **	$V = 120$ *
[ʔyː]	$V = 171$ ****	$V = 156$ **	$V = 145$ **
[bɐ]	$V = 153$ **	$V = 103$	$V = 108$
[dʊʁç]	$V = 149$ ***	$V = 129$ *	$V = 101$

2 and 4, which were formulated so as to shift the focus away from the verb, show slightly smaller prominences than sentences of type 1 and 3, respectively. By far the highest prominences appear in type 5 sentences, where the prefixes are unbound and placed at the end of the carrier sentences. Finally, unstressed bound prefixes (type 6) are slightly more prominent than function words in similar contexts (type 7). On the whole, similar results were shown for syllable duration values when compared across sentence conditions, even though the correlation between prominence and duration values was not very high (Pearson correlation: 0.31). Differences in syllable duration between conditions 3 and 4 as well as between 6 and 7, while remaining small, were opposite in direction from the corresponding prominence differences.

As the data were not normally distributed, Wilcoxon tests were used to evaluate differences across sentence conditions. Significant differences in duration and prominence were found between syllables in lexically stressed and unstressed prefixes ($W > 7200$, $p < 0.05$ for condition 2 vs. 3; $W > 7800$, $p < 0.01$ for condition 1 vs. 3 and 2 vs. 4). A significant effect of sentence stress on prominence means was found for syllables in lexically stressed prefixes ($W = 7863$, $p < 0.01$ for condition 1 vs. 2). There were no effects for sentence stress in lexically unstressed prefixes (conditions 3 vs. 4) and for differences between unstressed bound prefixes and function words in similar contexts (conditions 6 vs. 7).

Analysis of paired differences between sentence conditions for syllables spoken by the same speaker and in the same word confirmed the effect of lexical stress. Effects of sentence stress not only on prominence but also on duration were found for syllables in lexically stressed prefixes (see Tables 2 and 3). Examined individually, almost all syllables yielded higher prominence and duration values in stressed compared to unstressed prefixes, at least in focused verbs. This included the permanently unstressed syllables [bɐ] and [tɐ] in the bisyllabic prefixes "über" and "unter". Prominence differences for [ʔʊm] were only marginally significant ($p = 0.051$).

There seems to be a conflict between conveying different degree of sentence stress while maintaining the lexical stress distinction in unfocused sentence positions. In a comparison of prominence, only the syllable [ʔyː] showed positive effects of both word and sentence stress. Significant duration effects due to sentence and word stress were found for the syllables [ʔʊn], [tɐ], and [ʔyː].

For all syllables except [ʔʊn], differences in prominence and duration between conditions 3 and 4 as well as 6 and 7 remained insignificant. [ʔʊn] was more prominent as an unstressed prefix than as part of a function word (condition 6 vs. 7, $V = 135$, $p < 0.01$).

3.2. Acoustic similarity

To investigate overall similarity between syllables in different sentence conditions, amplitude envelopes were calculated for 4 frequency bands using an envelope sampling rate of 500 Hz, following the procedure in [11]. Similarities were determined by cross-correlating the envelopes from syllable pairs spoken by the same speaker and produced in the same word. Wilcoxon tests showed no difference in similarity between syllables in stressed vs. unstressed prefixes (conditions 1 and 2 vs. 3 and 4) or between syllables with or without sentence stress (conditions 1 and 3 vs. 2 and 4). However, syllables in stressed prefixes showed significantly greater similarity with the highly prominent realizations in separated prefixes (condition 5) than did syllables in unstressed prefixes (Table 4). Comparisons of similarities between conditions 1 and 5 vs. 2 and 5 yielded no such results for sentence stress.

In an individual examination of syllables, the effect of lexical stress was shown to be largely the result of the highly significant differences between pronunciations of the syllable [ʔyː] in stressed vs. unstressed prefixes. Differences between stressed and unstressed versions of the syllables [ʔʊm] and [ʔʊn] proved to be stronger when they were not in sentence focus.

On the whole, syllables seem to vary in the degree to which they differ across sentence conditions. Particularly the syllable [bɐ] was found to be very robust, followed by the syllable [tɐ]. This remained true even when only

Table 4: *Wilcoxon tests for similarities between syllables in stressed/unstressed prefixes and syllables in separated prefixes (*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$).*

syllable	1 and 5 vs. 3 and 5	2 and 5 vs. 4 and 5
all	$W = 7408$ ***	$W = 7655$ ***
[ʔʊm]	$W = 172$	$W = 247$ *
[ʔʊn]	$W = 200$	$W = 263$ *
[tɐ]	$W = 194$	$W = 221$
[ʔyː]	$W = 292$ ****	$W = 242$ *
[bɐ]	$W = 192$	$W = 162$
[dʊʁç]	$W = 203$ *	$W = 178$

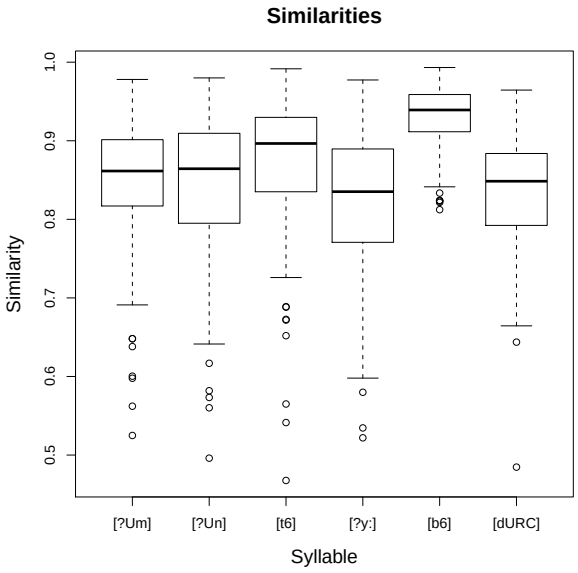

Figure 2: *Syllable similarities across sentence conditions 1, 2, 3, 4, and 6.*

bound prefixes were examined (Figure 2).

4. Discussion and Conclusion

This paper aimed to disentangle lexical, morphological, syntactic and semantic influences on prominence. The acoustic realization of a set of German verb prefixes forming prosodic minimal pairs was analyzed in a tightly controlled production study. Carrier sentences were constructed such that a systematic variation of sentence stress position, lexical stress position, and prefix boundedness was achieved. The realization of the intended reading of a particular sentence was enhanced by a picture displayed along with the sentence. Relative prominence was determined automatically on the basis of duration, pitch dynamics, intensity, and spectral emphasis of syllable nuclei. Additionally, syllable durations were calculated and acoustic syllable similarity across sentence conditions was computed by cross-correlating spectral envelopes for pairs of syllables in 4 frequency bands.

Unlike word boundaries, phrase boundaries had a strong positive effect on the prominence and duration of syllables preceeding them. As expected, lexical stress was shown to be an important influencing factor. Syllables in lexically stressed prefixes were more prominent, longer, and closer in pronunciation to prefixes at phrase boundaries than lexically unstressed syllables. Changes in sentence emphasis proved to be an influencing factor only for syllables in lexically stressed prefixes.

A more detailed examination showed that syllables differed in the extent to which they were affected by the various influencing factors. The effect of lexical stress was most consistent in focused sentence positions, where it even influenced syllables in stressed prefixes that were not stressed themselves. Changes in word and sentence stress affected almost all syllables in respect of at least one of the acoustic cues analyzed. Duration values were confirmed to be the most robust method of expressing both types of change (cf. [3]).

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