SECONDARY STRESS IS DISTRIBUTED RHYTHMICALLY WITHIN WORDS: AN EEG STUDY ON GERMAN

Johannes Knaus, Richard Wiese & Ulrike Domahs

Institut für Germanistische Sprachwissenschaft, Philipps-Universität Marburg, Germany
knaus@uni-marburg.de; wiese@uni-marburg.de; domahs@uni-marburg.de

ABSTRACT

The present paper report results of an ERP-study on German noun-noun compounds in which the influence of stress clash on stress positions within compounds is tested. In particular, it is examined whether secondary stress within a second constituent is affected by the stress pattern of a first constituent as well as by the main stress position of the second constituent. Stimuli used were polysyllabic compounds which allowed manipulating the stress positions such that alternative hypotheses about foot structure and its constraints could be tested.

The main result is that the preferred position for secondary stress in German is the initial syllable. Furthermore, the distribution of secondary stresses is computed within words, not within larger contexts: Stress clashes caused by these contexts do not influence the distribution of stresses.

Keywords: German, word stress, secondary stress, compounds, ERP

1. INTRODUCTION

The present paper deals with the questions how word stress and stress on higher levels of the prosodic hierarchy are related, and what the preferred positions of secondary stress in German are.

Within the relevant literature, there are conflicting assumptions on the relation of word stress and higher level stress. Some accounts (e.g. [8, 9]) claim that secondary stress is variable and depends on the rhythmical structure of the sentence in which they occur. Which syllable receives stress then is determined by the interplay of primary and secondary stresses of words in a sentence context. Accordingly, interactions of word stress patterns and rhythmical preferences should have a strong influence on stress placement. A second approach (e.g. [4, 7]) argues that stresses are determined by the internal structure of a word, i.e. its feet and syllables. This internal structure is built up independent of higher-level prosodic structures.
Empirical data on the distribution of secondary stresses is sparse and contradictory [3]. What are possible positions of secondary stress, and which are the preferred ones? Alternatively, one could doubt the existence of secondary stress at all in German loanwords [6]?

Generally, the paper addresses the following questions: is secondary stress derived from within the structure of the word, from the context of this word (here, a compound), or from both?

2. AN EEG STUDY ON GERMAN COMPOUND STRESS

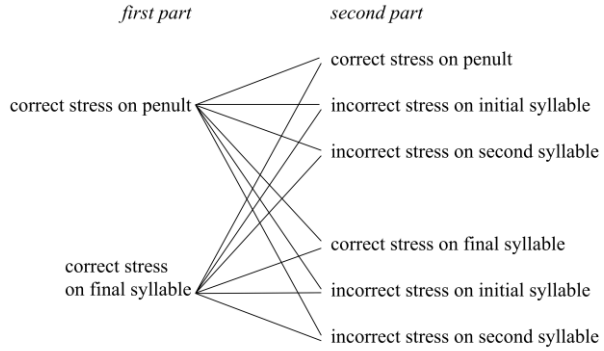
To shed light on these questions we conducted a neurolinguistic experiment on stress in complex German words. Previous EEG-studies on the processing of word stress in German [2, 5] have shown the sensitivity of this experimental method to manipulations of word stress: stress violations leading to illformed or dispreferred structures (e.g. **Vi(ˈta.min)* instead of *(Vi.ta)(ˈmin)*: (LL)(ˈH) becomes L(ˈLH)) produce significantly stronger electrophysiological effects (P3b) than violations maintaining the foot structure *(*(ˈVi.ta)(min):* (LL)(ˈH) becomes (ˈLL)(H)). Thus, the studies show the grouping of syllables into feet, and the potential stress positions in German words irrespective of main or secondary stress positions. Manipulations of main stress can therefore be used as a diagnostic tool to identify secondary stress positions. It is noteworthy that to date no explicit phonetic correlate of secondary stress has been found.

In the current experiment, participants (22 German monolinguals, 12 women) were presented with correctly and incorrectly stressed compounds embedded in a carrier sentence (*Er soll nun (Eu ˈropa)$_\omega$(enthusiˈasmus)$_\omega$ sagen* 'He is supposed to say …'). The task was to judge whether the critical word was stressed correctly or not (by pressing a button). The material was selected such that it allowed for the evaluation of metrical structure and their conditioning factors.

2.1. Method

- Stimuli were naturally spoken German noun-noun compounds, comprising a trisyllabic first part and a pentasyllabic second part, recorded at 44 kHz sampling rate, 16 bit (mono) using *Amadeus Pro* (HairerSoft) and a Beyerdynamic MC 930 electret microphone.
- The design of the stimuli is illustrated in Figure 1. The trisyllabic first constituent of the critical items was stressed either on the penult or the final syllable. These first parts were always stressed correctly. In the pentasyllabic second constituent, correct main stress appeared on the penult or the final syllable. These constituents were derived words, all comprising main and (supposed) secondary stresses. Following the rationale explicated in [2], possible secondary stress positions should be identifiable via main stress shifts. Therefore, manipulations are applied only to the second constituent in which main stress was shifted from the correct position to the initial or the second syllable. Compound main stress lies on the first part and our manipulations do not affect compound stress but word stress of the second constituent. The use of morphologically complex noun stimuli could not be avoided because of a lack of suitably long monomorphemic nouns.

Figure 1: Overview of the stimulus design and the 12 experimental conditions (2x2x3).



- This experimental design (Fig. 1) allowed us to investigate whether the stress shifts within the second part of the compound indicate possible secondary stress positions (i.e. heads of feet) and whether the position of main stress in the first part of the compound (stress context) has an influence on the processing of these stress shifts (i.e. clash avoidance effects, cf. [10]). For an example of each of the cases, see Figure 2.
- The set of stimuli consisted of 15 stimuli per condition, presented twice. Each pentasyllabic constituent appeared in each of the experimental conditions (i.e. once with stress in the correct position, and twice with stress in incorrect positions).
- In order to balance the number of correctly and incorrectly stressed words the stimulus set included also 30 filler items with stress on the first and second syllable each.
- EEGs were measured via 22 AgAgCl electrodes (C2 as ground, reference placed at left mastoid) and a *Brainvision* amplifier. Impedances were kept below 5 kΩ; EEG/EOG were recorded with a sampling rate of 250 Hz, filtered offline with a 0.3-20 Hz bandpass filter.
- Averages were calculated from the onset of the second part of the compounds up to 1900 ms post onset.
- For comparison of mean voltage differences between correct and incorrect conditions, two time windows were selected by means of visual inspection (from 330 to 580 ms for shift to the first syllable and from 500 to 900 ms for shift to the second syllable).
- ANOVAs were calculated for STRESSPOSITION (correct vs. initial or second syllable) over three BRAINREGIONS (frontal: F3, Fz, F4; central: C3, Cz, C4; parietal: P3, Pz, P4).

2.2. Results

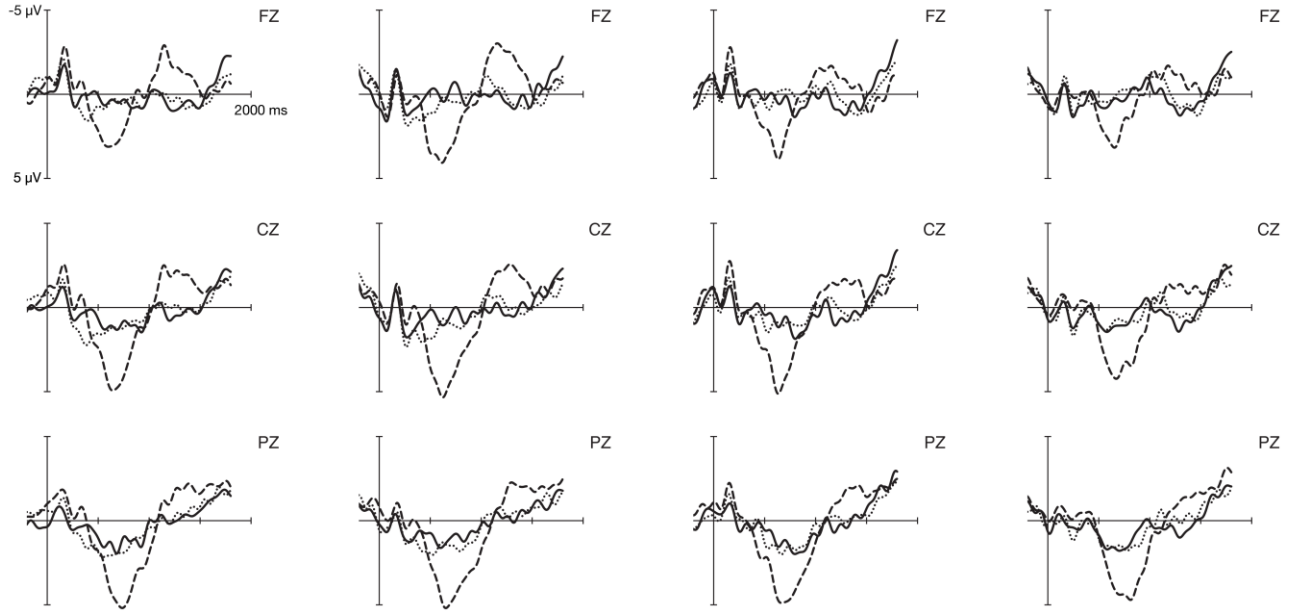
2.2.1. Behavioral data

Reaction times are not analyzed here, as participants had to react with a delay after the offset of the carrier sentence to avoid movement artifacts. Error rates were below 9% for most conditions, whereas the error rates for stress shifts to the first syllable ranged from 41% to 50%. Crucially, there were no differences between the stress contexts provided by the differently stressed first parts of the compounds.

2.2.2. ERP data

A comparison of the averaged EEG data of the correct conditions with the two conditions containing stress violations in the second part of the compounds revealed positivity effects (see Figure 2). In the following, it is outlined how stress context and main stress position of the second constituent modulate the positivity effects.

Figure 2: Grand average plots (midline electrodes) of correctly stressed pentasyllabic words (solid lines) and the same words with incorrect stress on the first syllable (dotted lines) and incorrect stress on the second syllable (dashed lines).



Eu'ropa-Enthusi'asmus
* Eu'ropa-'Enthusiasmus
* Eu'ropa-En'thusiasmus
"enthusiasm for Europe"

Parla'ments-Enthusi'asmus
* Parla'ments-'Enthusiasmus
* Parla'ments-En'thusiasmus
"enthusiasm for the parliament"

A'roma-Sensibili't ät
* A'roma-'Sensibilit ät
* A'roma-Sen'sibilit ät
"sensitivity to flavours"

Aggres'sions-Sensibili't ät
* Aggres'sions-'Sensibilit ät
* Aggres'sions-Sen'sibilit ät
"sensitivity to aggression"

Shifts within the second constituent with penultimate stress: Shifts from the penultimate syllable to the initial syllable evoked, irrespective of stress contexts (e.g. **Eu'ropa-'Enthusiasmus* and **Parlaments-'Enthusiasmus*), a positivity effect between 330 to 580 ms post stimulus onset ($F(1,21)=16.98$, $p<.001$ and $F(1,21)=7.52$, $p<.012$). Stress shifts to the second syllable *(En'thusiamus)* revealed an even larger positivity effects in both stress contexts (**Eu'ropa-En'thusiasmus* and **Parla'ments-En'thusiasmus*) between 500 and 900 ms post onset ($F(1,21)=27.76$, $p<.000$ and $F(1,21)= 41.31$, $p<.000$).

Shifts within the second constituent with final stress: Violations evoke asymmetrical effects. Stress shifts to the initial syllable evoke no positivity effect in neither stress context (e.g.**A'roma-'Sensibilität* and **Aggres'sions-'Sensibilität*) measured again within 330 to 580 ms ($F(1,21)= 3.07$, $p=.094$ and $F(1,21)>1$). In contrast, stress shifts to the second syllable produce enhanced positivity effects in both contexts (**A'roma-Sen'sibilität* and **Aggres'sions-Sen'sibilität*), again between 500 and 900 ms ($F(1,21)=35.46$, $p<.000$ and $F(1,21)=36.15$, $p<.000$).

2.3. Discussion

The present study aimed at finding evidence for potential secondary stress positions in derived German loanwords and, in addition, the factors which influence secondary stress positions. It is suggested that words bear initial secondary stress in multisyllabic words whose main stress allow for further prominent syllables (e.g. [1]). Alternatively, it has been suggested that secondary stresses of words are influenced by rhythmical alternations at the sentence level (e.g. [8]).

The present study replicates findings from earlier experiments on stress perception using a stress evaluation paradigm, as the electrophysiological effects obtained are again positivity effects, interpreted as instances of a P3b reflecting a task-specific process in [2, 4]. Again the occurrence and non-occurrence of the P3b tells us how stress positions are rhythmically distributed by means of feet within the domain of prosodic words. The first crucial result is that for neither analysis the stress context played a role. We did not find a greater acceptance of stress shifts to the second syllable in words with finally stressed first constituent than in stress contexts with penultimate stress.

The evaluation of stress shifts and the obtained ERP-results strongly suggest that the initial syl-

lable is the preferred secondary stress position in German. In this respect, it is noteworthy that shifts to the initial syllable produce no positivity at all in pentasyllabic words with final canonical stress. This shows a high acceptance of initial stress irrespective of the stress context. Clash contexts have no influence on the processing of the initial syllable. Thus, clash avoidance in words like **Aggres'sions-'Sensibilität* does not play a major role in the prosodic processing of the critical items. The suggestion is not that clash avoidance does not play a role in prosodic processing at all, but that the level of secondary stress is not affected by the level of compound stress. Feet are constructed within words independently of the phrasal context. This finding is corroborated by the analysis of the behavioural data. Shifts to the second syllable had significantly lower error rates, i.e., they were easier to detect, while shifts to the first syllable produced up to 50% error rates, i.e., participants were uncertain about the correctness of this stress position.

As regards stress shifts to initial syllables we find asymmetrical results for pentasyllabic words with final and penultimate stress. Whereas in the former case no P3b was obtained, the latter case produced a significant effect though not as pronounced as in shifts to second syllables. Our interpretation of the differentiated results is that a possible realization of secondary stress in finally stressed pentasyllabic words is expected more than in words with penultimate stress. This might be due to the distance between main stress and the left word boundary *((,Sen.si)(bi.li)('tät)* vs. *(,En.thu)-si('as.mus))*, or due to the better parsing conditions in finally stressed words opposed to words with penultimate stress.

Finally, our data provide evidence for the parsing routine underlying assignment of secondary stress. In linguistic theory, it is under debate whether main and secondary stresses result from the same parsing procedure or whether main stress is aligned to the right word edge and secondary stress to the left edge. For the alternative foot analyses see the following examples.

- ??En.(thu.si).(as.mus)
- (En.thu).si.(as.mus)

The less pronounced violation effect for words with stress shift to the first syllable as well as the high acceptance of initial stress in the judgements speak in favour of the second option with an initially parsed syllable; secondary stresses are aligned with the left edge of words [1]. Whether the parsing is quantity-sensitive or not is unsolved so far and has to be addressed in future studies. Rhythmical preferences within larger domains, for example within a compound, do not override this foot placement.

3. CONCLUSIONS

The preferred position for secondary stress in (pentasyllabic) German words is demonstrated to be the word-initial syllable. Stress clashes resulting from immediate context do not influence this overall preference. Within the constituents of a compound prosodic structures are built up independently of each other. This supports the idea that compounds are a special case of prosodic phrases rather than prosodic words [11].

In both clash and non-clash contexts, a stress shift to the initial syllable is tolerated, while shifts to the second syllable always are detected as incorrect. The lack of clash avoidance effects across word boundaries argues for the view that word prosody and prosody above the word are separate levels of prosodic structure and processing.

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