THE INFLUENCE OF SYLLABLE NUMBER AND TASK-RELATED ATTENTION ON THE PERCEPTION OF RHYTHMIC IRREGULARITIES: AN ERP STUDY ON GERMAN COMPOUNDS

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ABSTRACT

The present paper explores the processing of rhythmic irregularities in the form of so-called stress clashes in German noun compounds. This type of rhythmic irregularity has been found to be problematic as it induces higher costs in language processing. Moreover, the number of syllables in rhythmically irregular structures seems to play an important role for their correct perception. The present study thus concentrates on the influence of syllable number and task-relatedness and presents data from two ERP experiments. Their results show that stress clashes are only detectable if attention is clearly directed towards the prosodic structure, or if the words contain an even number of syllables and thus a preferred binary structure of prosodic feet.

Keywords: foot structure, stress perception, attention, word length, rhythmic regularity

1. INTRODUCTION

When spoken language is processed, information regarding the *lexical accent* as well as the *metric accent*, i.e. a harmonic rhythmical structure in form of an alternating sequence of stressed and unstressed syllables, is highly important. Sometimes, however, a lexical stress pattern has to be altered in favour of the rhythmic structure. This is especially the case with so-called *stress clashes* of two adjacent stressed syllables [15]. To separate the stressed syllables, a stress shift of secondary stress away from primary stress may take place. It occurs especially in compounds (*ˈHauptˌbahnhof* → *ˈHauptbahnˌhof* 'main train station') and phrases (*Terˈmin ˌabsagen* → *Terˈmin abˌsagen* 'to cancel an appointment'). These stress shifts, however, lead to a deviation from the correct lexical stress pattern. Despite this fact and although the application of stress shifts is optional, such shifts, also known as the Rhythm Rule [9], operate highly systematically in stress-timed languages such as German and English [1, 5, 17, 18]. Hence, rhythmic factors override the preservation of canonical lexical stress in order to avoid a stress clash structure [16].

The importance of both lexical and rhythmical regularity for language processing has been illustrated by a number of studies measuring event-related potentials (ERPs) [2, 3, 6, 8, 10, 11, 12, 13, 14]. According to the results of these studies, the brain clearly reacts to lexical and metrical stress violations if an expected structure is not met. Moreover, it could be shown that the detection of clear rhythmic violations is independent of attention, represented by an early negativity elicited irrespective of a matching rhythmical task [11, 13]. In contrast to previous investigated rhythmical violations, stress clashes are possible and rather subtle deviations which might therefore not be perceivable and detectable if prosody is completely unattended. Therefore, the early negativity effect found in previous studies for rhythmically irregular structures [2, 11, 13] might not be found if the deviation in question is very subtle and unattended.

But not only attention may influence the perception of this form of rhythmic deviation but also the prosodic structure in which they appear. Perception and production studies on German noun compounds [1, 18] showed that the number of syllables plays an important role in the detection of a stress clash. Comparing trisyllabic and quadrisyllabic compounds, it was shown that stress shifts and stress clashes are more easily perceived in compounds consisting of four syllables. The advantage of this syllable number is that it allows for the composition of two trochaic disyllabic feet.

Thus, 30 trisyllabic A(BC) and 30 quadrisyllabic A(BC) German compounds were used as stimuli in the two experiments of the present study. All compounds, either including a stress clash or a stress shift, were presented in two consecutive EEG sessions with different task settings. To inspect the critical role of attention and task relevance, implicit and explicit tasks were created.

It was hypothesised that stress clashes in quadrisyllabic compounds can be detected more easily due to their prosodic structure in comparison to trisyllabic compounds, irrespective of attention.

This should be seen in clearer evaluation ratings in the behavioural data of experiment 2 and in more pronounced ERP effects for the rhythmical deviations in quadrisyllabic compounds in both experiments. For experiment 1, it is expected that no effect can be found for stress clashes in trisyllabic compounds but only – if at all – for quadrisyllabic compounds.

2. EXPERIMENT 1

In the first experiment, all compounds were presented with an implicit task directing the participants' attention away from the prosodic structure of the sentences. The given task was a memory task: participants were instructed to listen to the presented sentences, to try to memorise as many words from the sentences as possible and to tick them off on a word list including 10 words in total. In this way, it was ensured that the participants listened to each sentence without paying attention to the metrical structure of the presented sentences.

Since related studies were able to show that rhythmical irregularities elicit an early negativity effect irrespective of a matching rhythmical task [11, 13], a similar negativity effect might be found for stress clashes in this experiment. However, due to the subtleness of the investigated deviation, it might be that this negativity is absent in this experiment or only elicited by stress clashes in quadrisyllabic compounds. The first experiment should therefore clarify whether even very subtle irregularities can be detected automatically irrespective of any task related attention to prosody and which role the number of syllables, or rather the structure of prosodic feet, plays in this detection process.

2.1. Method

2.1.1 Material

As stimuli, 30 trisyllabic (e.g. *Haupt-bahn-hof* 'main train station') and 30 quadrisyllabic (e.g. *Haupt-bahn-hö-fe* 'main train stations') A(BC) noun compounds were used. Here and below, A, B, and C refer to the morphological constituents of the compounds. All A- and B-constituents of these compounds are monosyllabic, whereas the C-constituents of the quadrisyllabic compounds consist of two syllables. In these cases, the final syllable contains an unstressable schwa-vowel (e.g. *Haupt-bahn-höfe:* /haʊpt.baːn.høː.fə/). The A-constituent carries main stress, secondary stress is on the B-constituent in clash conditions (e.g. *ˈHauptˌbahnhof* / *ˈHauptˌbahnhöfe)* and on the C-constituent in the shift conditions (e.g. *ˈHauptbahnˌhof* / *ˈHauptbahnˌhöfe)*. Each compound was presented with a stress clash or a stress shift to the participants, pseudo-randomised, and each compound appeared only once per condition within each block. The lexical comparability of the different compound types was secured by using singular and plural forms of the same compounds in both conditions. All compounds were embedded into a carrier sentence to ensure that the target phrases were located at identical prosodic phrase positions and not influenced differently by intonational properties. These carrier sentences were kept as natural as possible, i.e. not strictly rhythmically regular.

As filler items, correctly and incorrectly stressed forms of trisyllabic (AB)C noun compounds with primary stress on the initial syllable (e.g. Arm_A-band_B-uhr_C) were included.

All stimuli were recorded by a linguistically trained female speaker of German at a normal speech rate and were digitally recorded with a sampling rate of 44.1 kHz and a 16 bit (mono) sample size, using the sound recording and analysis software Amadeus Pro (version 1.5.3, HairerSoft) and an electret microphone (Beyerdynamic MC 930C) in an anechoic room.

2.1.2 Participants

25 right-handed German-speaking participants without hearing deficits and with normal or corrected-to-normal vision participated in this study. The data of five participants had to be excluded from analysis either due to a high number of artefacts (mainly eye blinks) per condition (more than 50%) or because they did not take part in both experimental sessions.

2.1.3 EEG recordings

The EEG measurement was by means of 64 active AgAgCl electrodes via a *Brainvision* amplifier. The reference electrode was placed at the left mastoid. Four electrodes measured the electrooculogram, i.e. horizontal and vertical eye movements. EEG and EOG were recorded with a sampling rate of 500 Hz and filtered offline with a 0.3 to 20 Hz bandpass filter. All electrode impedances were kept below 5 kΩ.

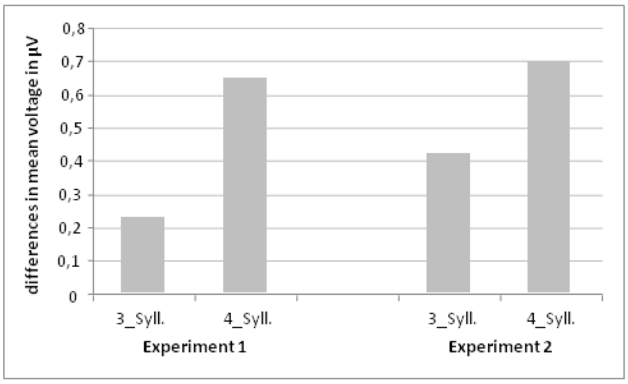
2.2. Results

For the EEG data, a multifactorial repeated-measures ANOVA was carried out with the factor REGION (left anterior (AF3, AF7, F1, F3, F5, F7, FC3, FC5), right anterior (AF4, AF8, F2, F4, F6, F8, FC4, FC6), left posterior (CP3, CP5, P1, P3, P5, P7, PO3, PO7), and right posterior (CP4, CP6, P2, P4, P6, P8, PO4, PO8) and the factor RHYTHM

CONDITION (well-formed vs. ill-formed). Averages were calculated from the onset of the B-constituent up to 1500 ms thereafter with a baseline of 200 ms preceding the onset. Time windows (200 – 400 ms) for each paired comparison were chosen based on hypotheses taken from the literature on rhythmical processing [2, 3, 4, 8, 10, 11, 13] and adjusted on the basis of visual inspection of the grand average curves. For effects with more than one degree of freedom, Huynh-Feldt [7] corrections were applied to the p-values.

The comparison of the conditions CLASH and SHIFT revealed a significant negativity effect only for quadrisyllabic compounds. The repeated measures ANOVA showed a main effect for the factor RHYTHM CONDITION [$F(1, 19) = 6.06$, $p = .024$, $\eta^2 p = .05$] but no significant interaction between the factors REGION and RHYTHM CONDITION [$F(3, 57) < 1$, $p > .05$, $\eta^2 p = .00$]. The analysed time window for trisyllabic compounds did not show a significant effect [$F(1, 19) < 1$, $p > .05$, $\eta^2 p = .00$]. Figure 1 provides a bar plot with differences in mean voltage between SHIFT and CLASH for trisyllabic and quadrisyllabic compounds measured at left posterior site.

Figure 1: Differences in mean voltage between CLASH and SHIFT in trisyllabic and quadrisyllabic words in experiments 1 and 2



3. EXPERIMENT 2

To compare the influence of attention and thus the importance of direct attention towards the prosodic structure, a more explicit task was used in experiment 2. In this experimental session, the set of stimuli was identical to experiment 1, but this time the participants were asked to judge the prosodic naturalness of the sentences heard. This way, the participants' attention was consciously directed towards the rhythmical features of each sentence.

3.1. Method

Material and EEG measurement were kept identical to those outlined for experiment 1, with a task modification. This time, it was the participants' task to decide whether the heard sentences sounded prosodically natural or not. This judgement should be made as accurately and as fast as possible by pressing one of four buttons. The assignment of buttons to four possible answers (natural, rather natural, rather unnatural, unnatural) was counterbalanced across participants.

The second experiment was undertaken at least four weeks after the first experimental session had been accomplished, as the same group of participants took part in both sessions. Only participants that completed both experimental sessions were included for data analysis.

3.2. Results

3.2.1. Behavioural data

Behavioural data were analysed by calculating the means of all responses for each condition. Each of the four possible response levels was allocated to a numerical value: 1 = natural, 2 = rather natural, 3 = rather unnatural, and 4 = unnatural. Data were further analysed as paired contrasts using a Wilcoxon signed-rank test.

Analyses of the two comparisons between CLASH and SHIFT showed that only quadrisyllabic compounds containing a stress clash were evaluated as less natural than the control condition SHIFT (mean 1.70 (SD .53) vs. mean 1.60 (SD .48); $Z(20) = -2.56$, $p = .01$). In contrast, no significant difference in the evaluation of trisyllabic compounds with stress clashes and stress shifts can be found (mean 1.60 (SD .44) vs. mean 1.62 (SD .46); $Z(20) = -.51$, $p > .05$).

3.2.2. ERP data

In this experiment, stress clashes in both compound types elicited a negativity effect in an early time window (200 – 400 ms). For trisyllabic compounds, the time window shows a stronger negativity for CLASH than for SHIFT (see also Figure 1). Although there was no main effect for the factor RHYTHM CONDITION [$F(1, 19) < 1$, $p > .05$, $\eta^2 p = .00$], the post-hoc analysis of a significant interaction of RHYTHM CONDITION by REGION [$F(3, 57) = 3.59$, $p = .047$, $\eta^2 p = .02$] displayed a left posterior negativity [$F(1, 19) = 7.07$, $p = .016$, $\eta^2 p = .04$]. In quadrisyllabic compounds, an early negativity was obtained in the same time window. The statistical analysis showed a main effect for the factor RHYTHM CONDITION [$F(1, 19) = 6.27$, $p = .022$, $\eta^2p = .06$] and no significant interaction between the factors REGION and RHYTHM CONDITION [$F(3, 57) < 1$, $p > .05$, $\eta^2p = .00$].

4. GENERAL DISCUSSION

The overall results show that the number of syllables and explicit attention towards the prosodic structure play an important role in the perception of stress clashes in German compounds. The main finding is an early negativity between 200 and 400 ms for CLASH in comparison to SHIFT. We interpret this negativity as an instance of a general error detection mechanism activated by the included rhythmic irregularity. This interpretation is supported by previous studies focusing on rhythmic deviations (e.g. 2, 11, 12, 13).

As was mentioned in the Introduction, previous studies showed that this rather general than language-specific error-related negativity can be found independently from special rhythmic or attentional task requirements [11, 13]. This suggests that the negativity for CLASH structures should also be elicited if the participants' attention was not directed towards the critical rhythmical structure. Previous studies presented clear rhythmical violations in strictly regular structures (cf. 11, 13) whereas the context in the present study was kept rhythmically natural, i.e. the carrier sentences did not contain an isochronous trochaic structure. Therefore, experiment 1 was designed to clarify the influence of attention on the elicitation of this component.

The results of experiment 1 are two-fold. Stress clashes elicit an early negativity effect, even when attention is not directed towards rhythm and prosody. The early negativity thus reflects the detection of rhythmic deviations irrespective of task requirements. However, this is only true for quadrisyllabic compounds. In compounds consisting of three syllables, in contrast, no negativity effect is elicited by stress clashes in comparison to stress shifts (see Figure 1). The number of syllables thus has a decisive influence on the detection and perception of this rhythmic deviation type. The effect of syllable number suggests that the alternation of strong and weak syllables is even more crucial for longer than for shorter words, in particular if the given structure allows for even trochees (strong-weak). This is the case for quadrisyllabic but not trisyllabic words, as the even number of four syllables can be structured into two well-formed disyllabic trochaic feet. Moreover, the final unstressable schwa-syllable in quadrisyllabic words demands a strong penultimate syllable and thus additionally fosters the rhythmically needed stress shift. A deviation from this even trochaic structure is thus more salient and easier to detect during language processing.

In experiment 2, stress clashes were evaluated as less natural than stress shifts only in compounds consisting of four syllables but not in trisyllabic structures. This result supports the finding obtained in experiment 1 that stress clashes are easier to detect in longer compounds and further supports the findings of previous studies [1, 18].

Regarding the ERP results, an early negativity effect was found for stress clashes in both trisyllabic as well as quadrisyllabic compounds when attention was generally directed towards the prosodic structure of the sentences heard. Furthermore, the effect strength seems to be modulated by the prosodic structure of the presented stimuli.

To summarise, the present study contributes to the discussion about factors influencing the processing of rhythmical structure. Both experiments suggest that rhythmical processing / processing of foot structure is dependent on word length. The longer a word, the more crucial is an alternating distribution of strong and weak syllables, resulting in well-formed and preferred prosodic feet. In addition, our study shows that clear cases of rhythmic irregularity produce error-detection responses even if the participants' task does not require attention to them.

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