THE PROCESSING OF WORD STRESS: EEG STUDIES ON TASK-RELATED COMPONENTS

Johannes Knaus, Richard Wiese and Ulrike Janßen

Institut für Germanistische Sprachwissenschaft, Philipps-Universität Marburg
knaus@staff.uni-marburg.de, wiese@staff.uni-marburg.de, janssenu@staff.uni-marburg.de

ABSTRACT

The present paper reports results from three ERP studies showing components which reflect the processing of different word stress violations dependent on distinctive task properties (explicit vs. implicit processing).

The main findings were that the presentation of an incorrect stress pattern led to an N400-like component indicating increased costs in lexical retrieval. Such a component is not dependent on the task during the processing of stress violations. Furthermore, an enhanced positivity effect (P300) reflects a stress mismatch detection only if stress judgment was explicitly required in the task.

Keywords: word prosody, stress perception, ERPs, N400, P300

1. INTRODUCTION

The present paper deals with the questions how far the language processor makes use of information from word stress, and in which way the usage of such information is influenced by different tasks.

To test this, we conducted three ERP studies in which the position of main stress in German trisyllabic words was manipulated. Between experiments, the processing tasks varied from explicit judgments on stress violation in different modalities to the implicit processing of stress errors. These tasks offer the possibility to examine processes as different as the lexical integration of stress information, matching of internally generated and externally presented patterns, and the evaluation of stress patterns.

2. EXPERIMENT 1

In order to find out how incorrectly stressed words are processed, we performed an ERP experiment in which participants were presented with correctly and incorrectly stressed words which should be judged explicitly. Previous ERP experiments using a stress discrimination task with bisyllabic words ([1], [4]) revealed inconsistent results with respect to stress effects on word processing.

2.1. Method

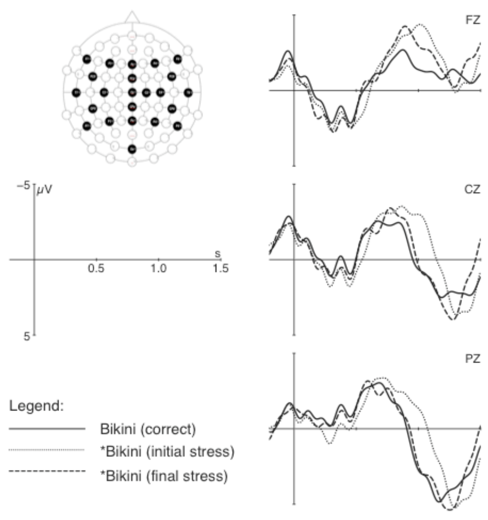
- Naturally spoken trisyllabic German words with penultimate stress containing either correct (e.g. *Bikíni*) or incorrect (initial: **Bíkini* or final: **Bikiní*) stress patterns were recorded. Sampling rate was 44 KHz, 16 bit (mono) using CoolEditPro (version 1.2; Syntrillium Software Corporation) and an electret microphone (Sennheiser K6, ME 66).
- The syllabic structure of the stimuli was either XV.XV.XV or XV.XVC.XV and did not contain reduced syllables (mean length of stimuli 1063 ms).
- Stimulus set of critical items consisted of 30 stimuli per condition.
- Each stimulus was spliced into an invariant carrier sentence (*Er soll nun* ***Bikini*** *sagen* 'He is supposed to say Bikini').
- Filler items were included to balance the number of correctly and incorrectly stressed words. Each stress pattern occurred in correct and incorrect conditions.
- Participants (18 German monolinguals, 13 fem.) had to judge the correctness of the presented stimuli.
- EEG measurement was by means of 22 AgAgCl electrodes via a *Brainvision* amplifier (C2 electrode served as ground electrode, reference electrode placed at left mastoid), impedances kept below 5 kΩ, EEG and EOG recorded with a digitisation rate of 250 Hz, filtered offline with a bandpass filter from 0.3 to 20 Hz.
- Averages were calculated from the onset of the critical items up to 1500 ms post onset with a baseline of 200 ms before stimulus onset.
- For comparison of mean voltage differences between conditions, three time-windows were selected (from 700 to 1200 ms, from 1100 to 1300 ms, and from 1300 to 1500 ms).

- ANOVAs were calculated for the factor STRESSPOSITION (correct vs. initial or final) over midline electrodes (Fz, Cz, Pz).

2.2. Results

Behavioral Data:
Error rates were below 4 per cent for each condition. Analysis of accuracy scores revealed no differences between correct and incorrect conditions ($F(2,34)<1$). Reaction time data were not analyzable, since reactions were only required after the offset of the carrier sentence to avoid movement artifacts.
ERP Data:
Negativity effects between 700 to 1200 ms: An overall comparison between conditions revealed a main effect for the factor STRESSPOSITION ($F(2,34)=29.01$, $p<.001$). Furthermore, a separate analysis of contrasts between the correct condition and each of the incorrect ones revealed that both types of incorrect stress evoked a negativity effect (*Bikíni* vs. **Bíkini*: $F(1,17)=64.72$, $p<.001$; *Bikíni* vs. **Bikiní*: $F(1,17)=5.98$; $p<.037$).
Positivity effects between 1100 to 1300 ms / 1300 to 1500 ms: Stress violations with final stress induced a positivity effect between 1100 to 1300 ms ($F(1,17)=7.68$, $p<.014$) and with initial stress between 1300 to 1500 ms ($F(1,17)=4.491$, $p<.05$). The positivity effect for initially stressed words is shifted in latency due to the preceding strong negativity in comparison to incorrect words with final stress (see Fig. 1).

Figure 1: Grand average curves of correctly (solid line) stressed words, words with incorrect antepenultimate stress (dotted line) and with incorrect final stress (dashed line).



2.3. Discussion

As shown in Fig. 1, the processing of incorrect words led to a biphasic ERP pattern: a fronto-central negativity effect between 700 and 1200 ms and a positivity effect between 1100 to 1300 ms or 1300 to 1500 ms, respectively.

With respect to the negativity, such a component can be interpreted as an instance of an N400 effect implying that a stress shift increases costs in lexical retrieval. Higher costs in lexical retrieval have also been found in behavioral studies (e.g. [3]). The late occurrence of the N400 effect can be ascribed to the presentation modality and the length of the auditory stimuli.

The subsequent positivity effect for incorrect conditions indicates the evaluation process related to the task requirements. Due to the prior negativity effect, the actual latency and strength of the evaluation effect is hidden. In the second experiment, we will investigate how a mismatch detection is processed when higher costs in lexical retrieval are excluded.

3. EXPERIMENT 2

If the negativity effect in the first experiment indicates an increase of activation load during the process of lexical access, we expect that such an effect would be excluded by the visual presentation of each critical stimulus prior to auditory presentation.

We hypothesized that the detection of a stress violation should produce stronger effects if participants compared an internally activated stress pattern with the presented one (additional results of experiment 2 relating to prosodic structure and other patterns of word stress are reported in [5]).

3.1. Method

Material, method and EEG measurement were mostly identical to those outlined for experiment 1, with a task modification only for the stimulus presentation: 24 participants (12 females) were first presented with each critical item *visually* (for 500 ms) before they heard the item with either correct or incorrect stress pattern.

For comparison of mean voltage differences between conditions, two time-windows were selected by means of visual inspection (from 500 to 800 ms and from 900 to 1400 ms).

3.2. Results

Behavioral Data:

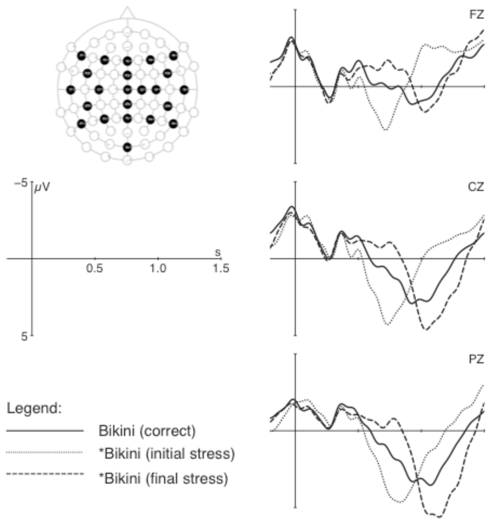
No decrease in accuracy was detected. Analysis of accuracy scores revealed no differences between correct and incorrect conditions (F(2,46)=1.716, p>.20).

ERP Data:

Positivity effects between 500 to 800 ms / 900 to 1400 ms: A separate analysis of contrasts between the correct condition and each of the incorrect ones revealed that both types of incorrect stress evoked an enhanced positivity effect (*Bikíni* vs. *Bíkini*: F(1,23)=33.304, p<.001; *Bikíni* vs. *Bikiní*: F(1,23)=13.913; p<.002) (see Fig. 2).

Negativity effect for words with final stress occurred between 500 to 900 ms (F(1,23)=31.98, p<.001); see Fig 2.

Figure 2: Grand average curves of correctly (solid line) stressed words, words with incorrect antepenultimate stress (dotted line) and with incorrect final stress (dashed line).



3.3. Discussion

In contrast to experiment 1, we did not obtain a biphasic ERP pattern, but mainly pronounced positive deflections. Positivity effects for the different stress violations occur in distinctive latencies: incorrect initial stress yielded positivity between 500 to 800 ms, and incorrect final stress between 900 to 1400 ms. Thus, ERPs seemed to be time-locked to the perception of an incorrect strong syllable.

We interpret the ERP findings to indicate that the perception of deviant stress patterns did not produce an N400 effect (the negativity effects observed for the two types of violations are deflections caused by the pronounced positivity), but only effects which seem to be task-related, i.e. related to a stress mismatch detection. Note that the participants' lexical access to the words was provided by the visual presentation of the items. In the literature, such effects have been labeled P300 effects (e.g. [6]). Interestingly, the latency of this type of effect seems to depend on the position of an ill-stressed syllable. This finding is compatible with the Metrical Segmentation Strategy account (e.g. [2]) which assumes that the relevant prosodic information for a word's segmentation is given by the position of main stress.

4. Experiment 3

In a voice discrimination task, the goal was to investigate the processing of stress deviations when the task itself does not require attending to prosodic information. In particular, it was to test the task dependency of the effects found so far, namely the N400 and P300.

4.1. Method

- Recording of naturally spoken trisyllabic words produced by two female speakers (parameters identical to Exp. 1).
- Test material was identical to Experiment 1.
- Each stimulus was presented in isolation and immediately repeated (inter-stimulus interval of 900 ms), by either the same or other speaker.
- Participants (20 German monolinguals, 9 fem.) had to judge whether the second word was produced by the same or a different speaker.
- EEG recording was identical to previous experiments. EEG was filtered offline with a bandpass filter from 0.5 to 20 Hz.
- Averages were calculated from the onset of the first word up to 1500 ms with a baseline of 200 ms before stimulus onset.
- Time window for mean voltage comparisons between correct vs. incorrect stress were chosen from 920 to 1420 ms.

4.2. Results

Behavioral data:

Error rates were appr. 1% for each condition. Analysis of accuracy scores revealed no significant difference between correct and incorrect conditions (F(2,38)=2.01, ns).

ERP Data:

Negativity effects between 920 to 1420 ms for incorrect conditions in comparison to the correct condition: An overall comparison between conditions revealed a significant interaction of the factors STRESSPOSITION and REGION (Fz, Cz, Pz) ($F(2, 38)=6.179$, $p<.002$). Post hoc analyses showed a significant difference between correctly stressed words and words with antepenultimate stress in frontal region ($F(1, 19)=6.272$, $p<.023$) and a global difference between correctly stressed words and words with final stress ($F(2,38)=10.24$, $p<.006$).

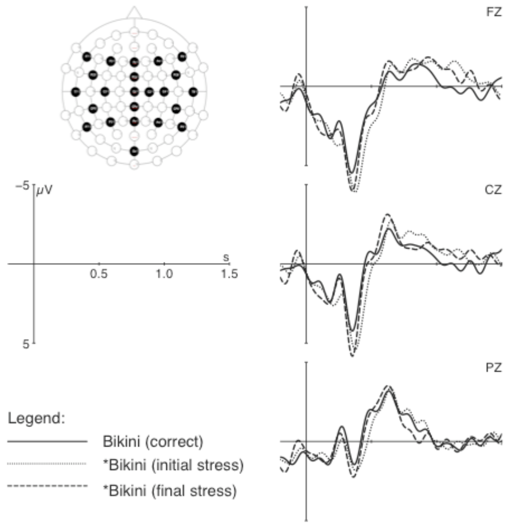


Figure 3: Grand average curves of correctly (solid line) stressed words, words with incorrect antepenultimate stress (dotted line) and with incorrect final stress (dashed line).

4.3. Discussion

In the third experiment in which participants had to discriminate voice, and not stress differences, we observed an enhanced fronto-central negativity for both types of incorrectly stressed words. As in experiment 1 we interpret such a negativity as an instance of an N400 effect. In contrast to the previous findings, no positivity effect occurred due to the task difference. Participants focused on voice instead of stress distinctions.

These findings demonstrate that even in implicit stress processing deviant prosodic patterns produce a mismatch during lexical retrieval.

5. GENERAL DISCUSSION

The findings of the present paper contribute to the question how the speech perception system deals with metrical information. In this respect, errors of word stress led to two different electrophysiological responses reflecting diverse cognitive processes.

First, a negativity effect occurred in experiments 1 and 3 where incorrectly stressed words led to an inhibition during the lexical retrieval process. This N400 effect, however, is not related to whether the task requires attention to stress violations.

As a second result, ERP measurements revealed a positivity effect in both Exp. 1 and 2, yet differing in strength and latency. We interpret such a component (P300) to be reflecting the explicit judgment of correct and incorrect stress as required by the evaluation task. In Exp. 1 the P300 is less pronounced and shifted in latency, as the evaluation task could be performed only after lexical retrieval was accomplished. Thus, the P300 interfered with the preceding N400 effect diminishing the amplitude in the positive deflections. In Exp. 2 this interference was avoided by presenting the critical stimuli visually prior to their auditory presentation. Therefore the task allowed a focus on stress judgment. Latency differences of P300 effects between Exp. 1 and Exp. 2 are due to distinct strengths of the N400. The absence of the positivity effect in Exp. 3 confirms that this effect is due to task-relevant match-mismatch processing rather than being due to perception of stress violations per se.

To summarize, the observed effects have two important implications for prosodic processing: i) violations of stress patterns evoke an N400 effect reflecting lexical inhibition which is an automatic process observable in both conscious and unconscious perception, ii) the explicit evaluation of stress patterns surfaces in P300 effects whose latencies are correlated with the perception of a strong syllable.

6. REFERENCES

[1] Böcker, K. B. E., Bastiaansen, M. C. M., Vroomen, J., Brunia, C. H. M., De Gelder, B. 1999. An ERP correlate of metrical stress in spoken word recognition. *Psychophysiology, 36,* 706-720.

[2] Cutler, A., Norris, D. 1988. The role of strong syllables in segmentation for lexical access. *J. Exp. Psychol. Human* 14, 113-121.

[3] Donselaar, van W., Koster, M., Cutler, A. 2005. Exploring the role of lexical stress in lexical recognition. *Q. J. Exp. Psychol. A, 58,* 251-273.

[4] Friedrich, C. K., Alter, K., Kotz, S. A. 2001. An electrophysiological response to different pitch contours in words. *Neuroreport, 12,* 3189-3191.

[5] Janßen, U., Wiese, R., Bornkessel-Schlesewsky, I., Schlesewsky, M. subm. Word prosodic hierarchies: Evidence from event-related potentials.

[6] Picton, T. W. 1992. The P300 wave of the human event-related brain potential. *J. Clin. Neurophysiol., 9,* 456-479.