NetWordS report

Recognizing morphologically complex words: Challenges of stylistic and regional variation

1. Purpose of the visit

It was the purpose of my visit to Tübingen, Germany, to examine how native German listeners adapt over time to reduced pronunciations of two different types of prefixes using electrophysiological methods. A regionally constrained reduction type was chosen (reduction of the inflectional prefix *ge-* to [k] common in Southern German and Austrian accents) and compared to a reduction type that is putatively unfamiliar in all parts of Germany and Austria (reduction of the derivational prefix *ver-* to [f]). ERP components like the N400 should be able to indicate if listeners have processing difficulties when hearing such reductions. Three groups of native German listeners (n ≈ 40 per group) were tested: a group of Northern Germans (unfamiliar with both reduction types), a group of Southern Germans (familiar with *ge*-reductions, but unfamiliar with *ver*-reductions) and a group of Northern Germans living in Southern Germany (somewhat familiar with *ge*-reductions and unfamiliar with *ver*-reductions). An additional control group was tested hearing the critical prefixed words in unreduced forms. The data of the Northern Germans not living in the South should show whether reductions are processed differently for inflectional versus derivational morphemes, as these listeners are equally unfamiliar with both reduction types. Moreover, we are interested in how familiarity with a reduction type influences processing. To address this issue, we will compare the results for the *ge*-reductions of the three listener groups. If some experience is sufficient to deal with this reduction, the Northern Germans living in the South should process reduced *ge*-words similarly to Southern German listeners. Additionally, we will test for short-term adaptation effects by examining the N400 effect over the course of the experiment. Here, we expect that listeners should adapt more easily to inflectional reductions than to derivational reductions, as the lexical morpheme is still intact in the first but not in the second case (i.e., *rauch(en)* 'to smoke' can still be found in *kraucht* -- for *geraucht* 'smoked' --, but *verleg(en)* 'to lose' cannot be found in *flegt* -- for *verlegt* 'lost'). This project should thus inform theories on the plasticity of speech recognition and on the representation of morphologically complex words.
Apart from the scientific purpose of investigating the research questions mentioned above, my visit to Tübingen also had training purposes for me. I gained experience in setting up and running a huge ERP experiment. Furthermore, I had the opportunity to learn a new analysis technique (using generalized additive models for the analysis of our data) and thus benefitted greatly from Prof. Baayen's expertise concerning statistical data analysis.

2. Description of the work carried out during the visit

We decided to split my visit to Tübingen in two parts. Before my first visit to Tübingen in May and June 2012, I selected the critical words to be reduced, created the sentences, recorded a native Austrian speaker whose German was adapted to Standard German, but who was still able to produce the reduced prefixes in a natural fashion. Additionally, the

EEG experiment was set up. As Prof. Baayen's lab was still under construction, I was allowed to use the EEG-lab of the Collaborative Research Centre (Sonderforschungsbereich) 833 "The construction of meaning – the dynamics and adaptivity of linguistic structures" at the University of Tübingen. However, this lab had not previously been used either and I had to get it running first. It took the first month (May 2012) to get the hardware working and to become acquainted with the software. In June, I started testing participants for the control group (who only heard canonical pronunciations) and Southern Germans (who heard reduced *ge*- and *ver*-words). Back in Nijmegen, I tested Northern Germans who had not lived in the South for a longer period of time. Initial analyses hinted at a possible gender difference. Therefore, we decided to increase the number of participants per group (initially 24) and to go for 20 females and 20 males per group. During my second visit to Tübingen in October and November 2012, I finished testing the control group and the Southern Germans. Furthermore, I run the group of Northern Germans living in Southern Germany. Participants, especially males, were hard to find for this last group. I therefore ended up with roughly one third male and two third female participants in this group. In total, I have tested 143 participants during my stay in Tübingen and 50 in Nijmegen for the EEG experiment. I could not use the data of 27 participants mostly because of too many alpha waves or blinks. Furthermore, I tested 19 participants for a cloze test: thirteen in Nijmegen and six in Tübingen. Unfortunately, there was not enough time left to analyze the EEG data fully with Prof. Baayen. We want to use generalized additive models (gams), a new approach for the analysis of EEG (and other) data.

3. Description of the main results obtained

In the EEG experiment, all four participant groups listened to 400 sentences in total, 80 of which were fillers. Four other sets of each 80 sentences ended in *ge*-past participles, *ver*-past participles, *be*-past participles and nonwords, respectively.
A cloze test was run to determine the cloze probabilities of our critical items (the respective past participles). In the cloze test, participants were presented with 240 sentences of the EEG experiment ending either in a *ge*-, *ver*- or *be*-past participle. First, these past participles were replaced by a gap and participants had to complete the sentences with up to seven answers. Then, participants saw the sentences again and had to rate the solution that was used in the EEG experiment on a 7-point scale. A one indicated that the solution was a bad completion of the sentence, while a seven meant that the solution fitted the sentence perfectly.
The data from this cloze test has been analyzed. The *ge*-participles that we used in the main EEG experiment were mentioned in 86% of the cases, the *ver*-participles were mentioned in 57% and the *be*-participles in 43% of the cases. This might already reflect a frequency effect as participles containing the derivational prefixes *ver*- and *be*- (that are likely to be less frequent than participles built with the inflectional *ge*-prefix) were mentioned less frequently. The difference between *ver*- and *be*-past participles can probably be explained by the higher constraints on the *be*-words. The *be*-past participles formed the basis for the nonwords. The nonwords should model a schwa-reduction of the *be*-prefix but result in a phonotactically legal sequence in German. Therefore, the choice for the first consonant of the stem was constrained (to /l/, /r/, /h/ and /s/) and it had to be

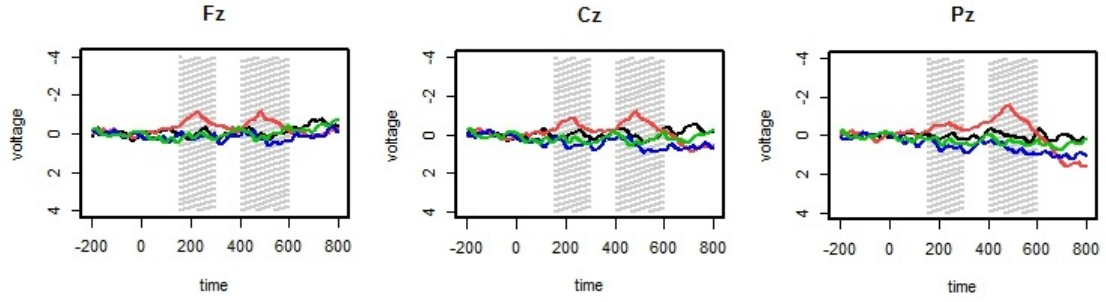
followed by a vowel (e.g., the nonword based on *beleidigt* 'insulted' was *blodigt*). Although participants did not come up with our solutions in all cases, they rated them very highly across all three types of past participles: On a scale from 1 to 7, with higher ratings meaning better fits, participants rated the *ge*-participles with 6.9, the *ver*-participles with 6.5 and the *be*-participles with 6.3 on average.

Sentences ending in *be*-past participles and nonwords were included in the experiment because the EEG data of canonical (*be*-)words and nonwords should provide us with a reference against which the reduced *ge*- and *ver*-words can be tested. That is, do listeners process reduced *ge*-words and/or reduced *ver*-words differently from nonwords and/or canonical words?

Control group (n = 41)

The control group was included in the design as another check of our materials. Participants in this group listened to sentences ending in canonical *ge*-, *ver*- and *be*-words and in nonwords. At all three main electrode sites (Fz, Cz, Pz), an N400 effect (i.e., a negative-going deflection peaking around 400ms after target onset) for the nonwords (in red in Figure 1) can be seen in the time window from 400-600ms after target onset. That is, we could replicate with our materials this nonword effect that is wide-spread in the literature. Interestingly, we see another negative-going deflection peaking around 200ms after target onset at the three main electrodes for the nonwords in red. This N200 is said to reflect a phonological mismatch between the expected and the incoming information. This mismatch could be elicited by the nonwords as they start with a consonant cluster whereas participants probably expect a CV or VC syllable that past participles generally start with in German. Importantly, preliminary analyses do not show a significant difference between the canonical *ge*-, *ver*- and *be*-words (represented by green, blue, and black lines respectively). That is, the only processing difficulties that arise (N200 and N400 effects) are caused by nonwords indicating that our materials function as they should.

Figure 1. ERP-results for the three main electrodes Fz, Cz, and Pz of the control group who listened to canonical *ge*-words (in green), canonical *ver*-words (in blue), canonical *be*-words (in black) and nonwords (in red). Time is displayed in ms with 0 being target onset.

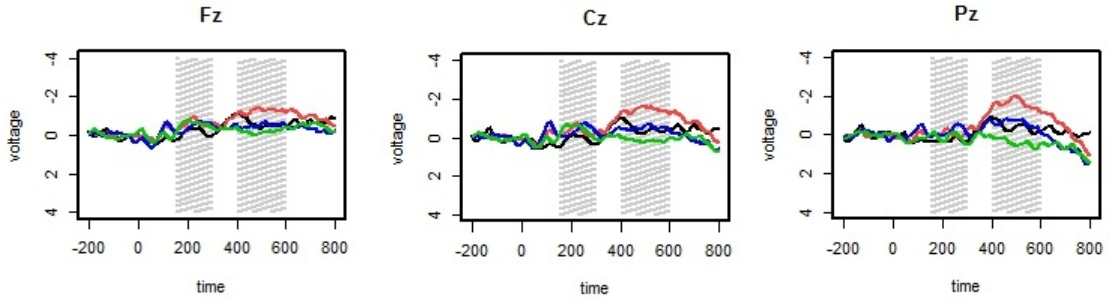


Northern Germans (n = 42)

The ERP-results of the Northern Germans that were tested in Nijmegen and had not lived for a longer period of time in Southern Germany or Austria are displayed in Figure 2. As can be seen, the N400 effect for the nonwords in red gets more pronounced the more

posterior the electrode site is (that is from electrode Fz over electrode Cz to electrode Pz). Also the difference between the reduced *ge*-words (in green) on one hand and the reduced *ver*-words (in blue) and canonical *be*-words (in black) on the other hand gets larger from electrode Cz to electrode Pz. This is confirmed statistically by a significant interaction between Condition (*ge*-words, *ver*-words, *be*-words, nonwords) and Electrode (Fz, Cz, Pz) in the N400 time window. In the N200 time window, the reduced conditions and the nonwords deviate from the canonical *be*-words only to a small extent. This difference reaches significance for the nonwords at electrode Fz, and for the reduced *ge*-words at electrode Cz. Thus, apart from the expected N400 effect for the nonwords, the Northern Germans show processing difficulties with the reduced *ver*-words (N400 effect) and treat them differently than the reduced *ge*-words. For the reduced *ge*-words, there is a small N200 effect indicating that problems with this reduction type can be overcome fast.

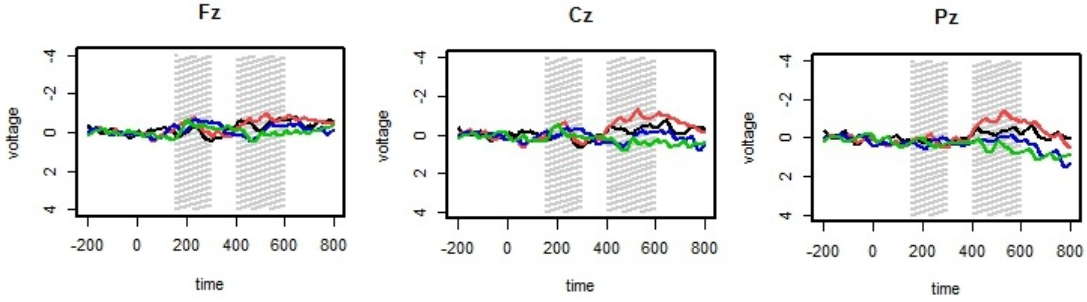
Figure 2. ERP-results for the three main electrodes Fz, Cz, and Pz of the Northern German participants who listened to reduced *ge*-words (in green), reduced *ver*-words (in blue), canonical *be*-words (in black) and nonwords (in red). Time is displayed in ms with 0 being target onset.



Southern Germans (n = 42)

Figure 3 displays the ERP-results of the Southern German group who listened to the same materials as the Northern German group, that is to nonwords (in red), to canonical *be*-words (in black), to reduced *ge*-words (in green) and to reduced *ver*-words (in blue). As for the Northern Germans, the N400 effect for the nonwords increases over electrode sites (from Fz via Cz to Pz). However, the reduced *ver*-words seem to be processed differently as they do not cross the line of the canonical *be*-words in the N400 time window (400-600ms). Preliminary statistics show a significant interaction between Condition and Electrode in the N400 time window. Interestingly, there is no significant difference between the reduced *ge*-words (green line) and the reduced *ver*-words (blue line). That is, the Southern Germans do not seem to be bothered by the reduced *ver*-words. In the N200 time window (150-300ms), the lines for the four conditions overlap. There is no significant difference between conditions indicating that none of the reduced words nor the nonwords are difficult to process at that stage.

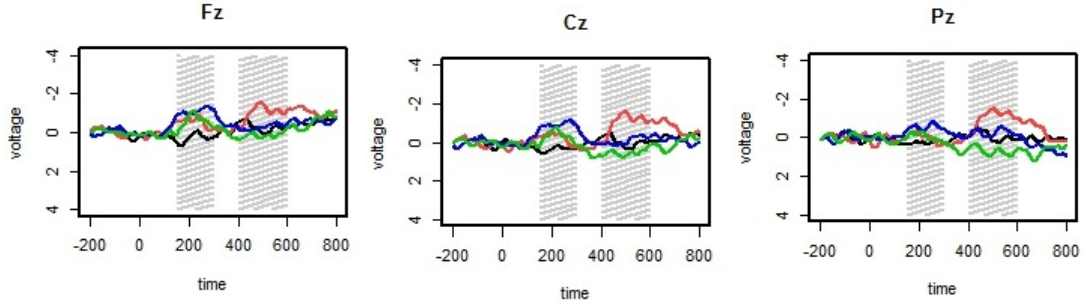
Figure 3. ERP-results for the three main electrodes Fz, Cz, and Pz of the Southern German participants who listened to reduced *ge*-words (in green), reduced *ver*-words (in blue), canonical *be*-words (in black) and nonwords (in red). Time is displayed in ms with 0 being target onset.



Northern Germans living in the South (n = 41)

The ERP-results for the Northern Germans living in Southern Germany are shown in Figure 4. Participants in this group listened to the same materials as the Northern Germans and the Southern Germans. Again, it can be seen that the size of the N400 effects (for nonwords and reduced ver-words) increase over electrode site. The interaction between Condition and Electrode is significant in the N400 time window. The Northern Germans living in the South show a pattern similar to the "pure" Northern Germans (i.e., those not living in the South), as they do not process reduced *ge*-words and reduced *ver*-words in the same way either (contrary to the Southern Germans). The reduced *ver*-words also pose difficulties for them (N400 effect). In comparison to the Northern German group, the pattern for the Northern Germans living in the South is more pronounced in the N200 time window. Statistics reveal a significant interaction between Condition and Electrode in that time window. There are N200 effects for the nonwords, reduced *ge*- and reduced *ver*-words at electrodes Fz and Cz. At electrode Pz, there is still an N200 effect for reduced *ver*-words. That is, the Northern Germans living in the South are more sensitive in detecting phonological mismatches. For the reduced *ge*-words, they can overcome their processing difficulties very fast. This is not the case for the nonwords and the reduced *ver*-words.

Figure 4. ERP-results for the three main electrodes Fz, Cz, and Pz of the Northern German participants living in Southern Germany. These participants listened to reduced *ge*-words (in green), reduced *ver*-words (in blue), canonical *be*-words (in black) and nonwords (in red). Time is displayed in ms with 0 being target onset.



Overall, the control group showed that we should be able to find N200 and N400 effects for the nonwords in all groups. This was indeed the case. The only exception are the Southern Germans who did not show an N200 effect for the nonwords. However, as

schwa-reductions are very common in Southern Germany, the beginning of the nonwords do not mismatch their expectation. So, this finding is actually in line with our hypotheses. All other effects we find should then be due to the fact that the words were reduced. In the N200 time window, the Northern Germans, regardless whether they were living in the South and therefore at least somewhat familiar with reductions, showed effects for the nonwords, the reduced *ge*-words and in part for the reduced *ver*-words. They were able to overcome their processing difficulties with the *ge*-reductions, but not with the nonwords and the *ver*-reductions. The Southern Germans, on the other hand, did not show any processing difficulties in the N200 time window and were also not bothered by the *ver*-reductions.

Short-term adaptation

Splitting the ERP-data in halfs to investigate short-term adaptation only revealed an effect for the Northern German group for the reduced *ge*-words. Splitting the data in halfs and having therefore up to 40 items in one category might, however, have been a too crude method. The literature suggests that adaptation might be accomplished after as few as ten items. Further analyses are required.

Reductions resulting in illegal sequences

The 80 *ge*-participles and the 80 *ver*-participles were chosen so that they would result in illegal phonotactic sequences in 50% of the cases. Figures 5 and 6 show the ERP-results for the three main electrodes (Fz, Cz, Pz) of the Southern German group for legal and illegal *ge*- and *ver*-reductions. Legal *ge*-reductions are represented by green lines, legal *ver*-reductions by blue lines and illegal reductions by orange lines. The pattern, here illustrated for the Southern German group, is consistent also for the two Northern German groups. Figure 5 shows that *ge*-reductions resulting in illegal sequences do not evoke an N200 effect, but differ in the N400 time window from the *ge*-reductions resulting in legal phonotactic sequences. The *ver*-reductions, however, show an N200 effect for the illegal condition. That is, *ver*-reductions resulting in illegal phonotactic sequences pose processing difficulties initially. These, however, can be overcome fast and listeners seem to be more troubled by reductions resulting in legal phonotactic sequences (N400 effect).

Figure 5. ERP-results for the three main electrodes Fz, Cz, and Pz of the Southern German group. Green lines indicate *ge*-reductions that resulted in legal phonotactic sequences. The orange lines represent *ge*-reductions that resulted in sequences that are phonotactically illegal in German. Time is displayed in ms with 0 being target onset.

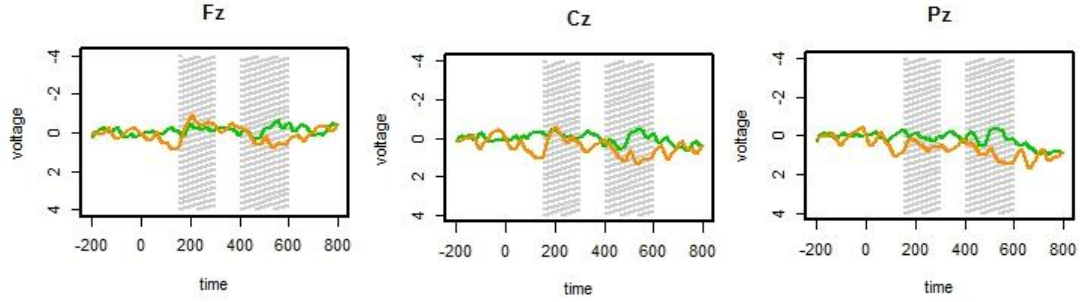
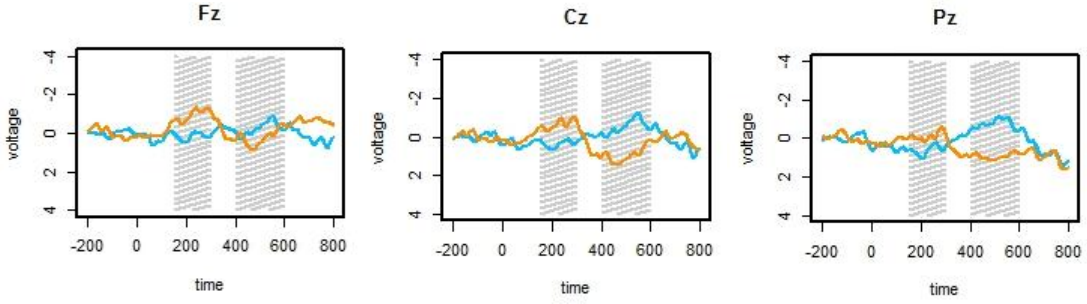


Figure 6. ERP-results for the three main electrodes Fz, Cz, and Pz of the Southern German group. Blue lines indicate *ver*-reductions that resulted in legal phonotactic sequences. The orange lines represent *ver*-reductions that resulted in sequences that are phonotactically illegal in German. Time is displayed in ms with 0 being target onset.



In summary, there is ample evidence that inflectional *ge*- and derivational *ver*-reductions are not processed in the same way by the different listener groups. The Northern German groups have problems processing the derivational *ver*-reductions (N400 effect), while they can overcome the difficulties imposed by inflectional *ge*-reductions (N200 effect) very fast. In contrast, the Southern Germans do not seem to be troubled by either *ge*- or *ver*-reductions. This was expected for the *ge*-reductions as they are very common in Southern Germany, but it is a surprising finding concerning the *ver*-reductions. Another corpus study has to be conducted to see whether Southern Germans do in fact produce the kind of *ver*-reductions used in this experiment. So far, it seems that listeners can only adapt to inflectional *ge*-reductions in the short term. This would confirm our hypothesis that reductions of inflectional morphemes are easier to adapt to, but the finding still has to be confirmed by more detailed analyses. Another striking finding is the difference in processing of reductions that result in legal and illegal phonotactic sequences. It seems that reductions leading to illegal sequences pose problems initially (N200 effect for illegal *ver*-reductions), but in the end these reduced words may be better or faster recognized than the legal reductions (there is an N400 effect for legal sequences). This pattern is more pronounced in the *ver*-reductions (see Figure 6), but can be found in the *ge*-reductions as well (see Figure 5).

4. Future collaboration with host institution

Prof. Baayen has invited me to come back to Tübingen in January 2013 to analyze the EEG data more thoroughly using gams.

5. Projected publications / articles resulting or to result from the grant

We plan to write this project up as a one-experiment paper which will probably be submitted to Journal of Cognitive Neuroscience. The analysis done with Prof. Baayen may be integrated into this paper as an alternative method of analysis to the traditional ANOVAs. Another possibility is to publish the new analysis using gams in a separate paper. Furthermore, the data will be presented at TeaP (Tagung experimentell arbeitender Psychologen / Conference of Experimental Psychologists; http://www.teap.de/index.php/teap/vienna) in March 2013 in Vienna.

6. Other comments

During my second visit to Tübingen, I had the opportunity to participate in a two-day statistical modeling workshop on gams (generalized additive models) and mers (mixed effects regressions) organized by Prof. Baayen and his group.
Furthermore, I was invited to give a guest lecture in Prof. Dr. Andrea Weber's proseminar in English linguistics on "Phonetics and speech perception" where I presented parts of my research to first-year students.