Improving the Prediction of German Lexical Stress

Petra S. Wagner
Institut für Kommunikationsforschung und Phonetik, Universität Bonn, Germany
E-mail: wagner@ikp.uni-bonn.de

ABSTRACT

Traditional approaches have regarded German stress to be predictable by localizing the initial stem syllable. Later, Metrical Phonology localized German stress close to the right edge of the stem, depending on the syllable weight. It will be shown that an algorithm based on a polytomous scale of syllable weight rather than a dichotomous one (heavy - light) is well able to predict German lexical stress. However, within the word class of proper names the algorithm fails. Here speakers of German appear to place stress on the left rather than the right edge of the stem. A closer look at the phenomena shows that this is not due to a preference of initial stress in historically older proper names but rather a rhythmic preference for trochees and dactyls. This appears to be evidence for a diachronic process where the influence of syllable weight has increased and become more important than a specific rhythmic pattern. This quantity sensitivity has not yet reached the peak of its influence in the diachronically older proper names.

1. INTRODUCTION

There are two competing views on German lexical stress placement, a traditional one, arguing for Germanic initial stem stress (for example [1]), and one in the tradition of Metrical Phonology looking for stress towards the right edge of the stem (for example [2]). The former approach regards German to be quantity sensitive with heavy syllables attracting stress. This paper is concerned with an evaluation of these views. First, a prediction algorithm based on the view proposed by Metrical Phonology is outlined. It is shown that most prediction errors occur in words ending in two light syllables. Thus, a perception experiment is presented showing the quantitative sensitivity of disyllabic German words consisting of two light syllables, depending on the sonority of the syllable rhyme. An extension of the German syllable weight hierarchy is argued for. Next, it is shown how the prediction accuracy of the algorithm drops dramatically on a list of proper names. Here, apparently, initial stress occurs much more often than elsewhere in German which might be an argument for the often supposed rule of German being stressed in the initial stem syllable. A decision tree which was trained on the proper names list, has to tell a different story: In the prediction of proper name stress, syllable weight plays less of a role than a rhythmic preference for trochaic and dactylic pattern rather than iambic ones. This leads to a preference for initial stress in short names. But syllable weight still appears to play a role in stress placement of proper names, albeit a less influential one. Dactyls ending in schwa and trochees ending in heavy syllables are avoided. Both of these tendencies support an alternating rhythmic pattern.

2. THE PREDICTION ALGORITHM

A simple prediction algorithm for inflected but not compounded words has been implemented based on Metrical Phonological insight about German lexical stress (compare [3]). The algorithm relies on a classification of syllables into the weight categories **heavy**, **light** and **schwa**. Each syllable is categorized as one of these three types based on the classification suggested by [4]. This classification can be formally described with the following regular expressions:

- Schwa: $C^{+}[ə|ɐ|n̩|m̩|ŋ|l̩]$
- Light: $C^{+}V[V|C]$
- Heavy: $C^{+}V[V|C]C^{+}$

The core rules of the prediction algorithm are very simple:

```
if (last syllable of the word is heavy){
     last syllable = stressed;
     }
else if (penultima is non-schwa){
     penultima = stressed;
     }
else {
     most right non-schwa syllable = stressed}
```

Prior to prediction of lexical stress, each word must be cleared of any unstressable affixes (see [3] for a list). Different other rules inspired by Metrical Phonology have been tested but in the end, the very simple approach proved sufficient. Despite its simplicity, the algorithm worked with an error rate of 4.17% on manually transcribed data [5]. This result is similar to the accuracy reached by data-driven algorithms (for example [6]). However, an analysis of the prediction errors showed most errors in disyllabic words consisting of two light

ISBN 1-876346-48-5

syllables. Here, our algorithm predicts stress on the first syllable, because only heavy finals attract stress. In many cases, this is incorrect (for example **Eßzétt, Hotél, Apríl, kapútt, Prográmm, Radáu, …**). This might indicate that stress placement on final syllables has other reasons than syllabic weight. However, an evaluation of the algorithm showed that the rule predicting stress on heavy finals is the most important one of all - if it is omitted, the prediction error rises to 9.22%. Therefore, the assumption of German being a quantity sensitive language appears to be correct. If the stress patterns of disyllabic words consisting of two light syllables are to be explained on the basis of syllabic weight also, the initial syllable-weight hierarchy needs to be altered.

3. PRODUCTION STUDY: INFLUENCE OF SYLLABLE WEIGHT ON LEXICAL STRESS

The motivation for this experiment was to question the syllable weight hierarchy introduced previously. There are several possible candidates for heavy or "heavier" syllables that we have previously classified as light. Among them are

- Syllables ending in a long monophthong
- Syllables ending in a diphthong
- Syllables beginning with a complex onset
- Syllables ending in a highly sonorous coda

If these syllables are indeed heavy they ought to attract stress on the last syllable in disyllabic words, at least if they were preceded by a very light syllable. In order to test this hypothesis, 44 disyllabic nonsense words were created on the basis of the syllables given in **Table 1**. These nonsense words were then used as stimuli in a production experiment in order to find out preferences of stress placement. As other studies have previously shown [7], onset consonants play only a marginal role in stress assignment and consequently syllable weight. Therefore, only the syllable rhymes are varied systematically in the production study.

First Syllable	Second Syllable
zɔm zo: zɔʏ ʔo:	bu: ba: baɪ bu:e̯ bɪn bɪl bat bɔk brɪt brɪl ʃprɪt

Table 1: Syllables for Nonsense Stimuli Words

The stimuli were chosen such as to make a graphemic representation unambiguous. These graphemic representations of the stimuli were embedded into very complex sentences which were read by 15 phonetically untrained native speakers of German. The speakers had to answer a distraction question after the production of each sentence, in order to avoid a repetition of a stress pattern due to a listing effect. The location of lexical stress was then determined perceptually by a phonetic expert. Overall, the results support the clear preference of stressing the penultima (χ^2, $p<0.0001$) given two light syllables as it is implemented in the prediction algorithm. Final syllables ending in a monophthong and those ending in a non-sonorous coda consonant were able to attract stress in very few exceptional cases. Final syllables ending in diphthongs received stress more often but still far from regularly or in the majority of cases. So there are hints that diphthongs are slightly heavier than long monophthongs but the results are far from conclusive concerning this point. Given an open penultimate, there is a tie (i.e. no significant preference) between subjects stressing the penultimate syllable and subjects stressing the last syllable. However, given a closed penultimate, stress clearly falls on the penultimate itself (χ^2, $p<0.0001$). Thus, the hypothesis that closed syllables are heavier than open ones, receives a lot of support. Final syllables are only stressed significantly more often if the final syllable ends in a sonorant (χ^2, $p<0.05$). This pattern becomes clearer if the penultimate is an open syllable (χ^2, $p<0.0001$). An additional rule based on this more fine-grained analysis of syllable weight is able to predict the stress pattern of those words where our initial algorithm failed.

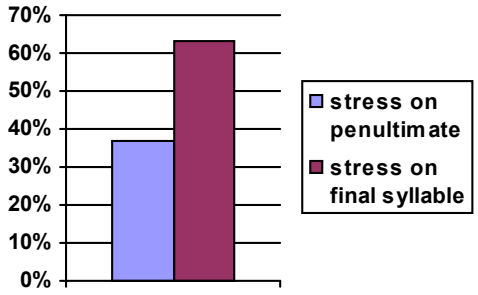

Figure 1: Stress distribution for open penultimate and final syllables ending in sonorant.

Based on this production experiment, our original German syllable weight hierarchy is thus enriched in the following way:

- Schwa: $C^+[ə|ɐ|n̩|m̩|ŋ̩|l̩]$
- Very light: C^+VV
- Light: $C^+VC_{obstruent}$
- Semi-heavy: $C^+VC_{sonorant}$
- Heavy: $C^+V[V|C]C^+$

4. LEXICAL STRESS IN PROPER NAMES

If the algorithm described in Section 2 is applied to a list of Christian names taken from telephone books ([8]; 6867 tokens after proofreading the original list), the error rate rises up to 18.32%. Even taking into account that proper names probably contain many stress patterns deviating from standard prosody, this result is disappointing. It is interesting, that the error rate can be greatly reduced down to 9.5% if the – previously very important - rule stressing heavy final syllables is left out. A qualitative evaluation of the cases where the algorithm failed yields the impression of a clear preference for initial stress in proper names even given a heavy final syllable (cf. Table 2).

Róman, Gúndolf, Náthan, Áugust, Héidrun, Ármin, Flórian, Káthrin,

Table 2: Names with initial stress and heavy finals

Such a pattern is consistent with the traditional concept of Germanic stress placement on the stem initial syllable. However, a rule preferring word initial lexical stress does not improve the prediction accuracy at all – on the contrary, penultimate stress appears to be the preferred pattern, especially in four-syllabic words. This might indicate a conflict between historically older Germanic initial stress and the modern preference for placing stress towards the right edge of a word. It is interesting, that in prosodic German minimal pairs the proper name variant often receives initial stress, whereas the noun carries final stress (see Table 3).

Róman (*male Christian name*) vs. Román ("novel")
Kónstanz (*city name*) vs. Konstánz ("constancy")

Table 3: Prosodic minimal pairs in German

Thus, influence of syllabic weight appears to be less important in predicting stress on proper names. Such a diachronic conflict between initial and final stress preference has been reported for English proper names as well [9]. But initial stem stress is not the answer to a successful prediction of lexical stress in proper names either. Solutions to this problem are sought below.

7. INTERPRETATION OF A CLASSIFICATION TREE PREDICTING PROPER NAME STRESS

Syllable weight is obviously less influential in stress assignment on proper names. Thus, the hypothesis to be tested next is that stress placement on proper names is described as a rhythmic phenomenon rather than a preference for initial stress. In order to gain information about the relevant parameters for lexical stress assignment in proper names a classification tree is trained and interpreted using the C-Tree Software [10]. The classification tree was built with the list of proper names used for the evaluation of the prediction algorithm in Section 3. 10% of the data were used as the test set. In order to gain information about interactions between syllable weight and rhythmic preferences, the only predictor variables were the weight of the different syllables within the word according to the original weight classification described in Section 2 and the number of syllables within the word. A much simplified representation of the resulting classification tree is given in Figure 2. The prediction accuracy of the classification tree was not very good but similar to the one reached by the adapted algorithm in Section 1, namely 10.6% error on the training and 12.6% on the test set. An interpretation of the classification tree yields the following weight-related results: Whenever there is a final schwa, stress falls onto the penultimate syllable. Obviously, German speakers avoid dactyls ending in schwa and prefer the strong lexical stress next to a schwa (cf. **Hélena** vs. **Helénə**). Lexical stress is placed much less frequent prior to light syllables. Here, final dactyls are preferred (in words consisting of 5 syllables) or at least similarly frequent (in words consisting of 3 syllables, for example **Paméla** vs. **Mónika**). In four-syllabic words, speakers are quite reluctant to place stress further near the beginning of the word which would result in an initial iamb - but such patterns do exist (**Verónika**). Obviously, there is a clear preference for trochaic and dactylic feet rather than iambic ones. This picture changes when looking at names consisting of three syllables. Here, we find an overall preference for stressing the first syllable (dactyl) but a final schwa forces, a final light syllable allows the word to end in a trochee/begin in an iamb. Altogether, the heavy finals restriction leading to final stress elsewhere proves to be almost nonexistent in Christian name stress. Even though in some cases it can be presumed in four-syllabic words (37% of the names with a heavy final are stressed on it), penultimate stress resulting in two trochees across the word remains by far the most frequent pattern. It is interesting that heavy final syllables even appear to result in a stress shift towards the left edge of the word rather than attracting it. When a word ends in a heavy syllable, the word tends to end in a dactyl. Overall, three general preferences can be named for German stress patterns in Christian names:

- The preferred rhythmic patterns are trochees and dactyls rather than iambs.
- Dactyls ending in schwa are avoided, leading to stress placement before schwa.
- Trochees ending in heavy syllables are avoided, leading to stress placement further to the left.

ISBN 1-876346-48-5

Overall, these preferences account for a large number of phenomena and also explain the relative instability of names ending in light syllables. In such cases, there exists variability rather than one typical stress pattern.

8. CONCLUSION

We have shown that German lexical stress can be explained by an interaction between rhythmic preferences and quantity sensitivity where the latter is less dominant in proper names. Syllable weight can explain more phenomena if a simple classification into heavy vs. light syllables is replaced by a more complex syllable weight hierarchy. The preferred rhythmic patterns in German are trochees and dactyls, where trochees prefer ending in very light syllables, but dactyls rather end in heavy ones thus helping the word to a more alternating rhythmic structure.

REFERENCES

[1] Wurzel. W.U. (1980). Der deutsche Wortakzent. Fakten-Regeln-Prinzipien. Ein Beitrag zu einer natürlichen Akzenttheorie. *Zeitschrift für Germanistik*, 1:299-318.

[2] Jessen, M. (1998). *German*. In Hulst, H. van der (ed.). *Word Prosodic Systems in the Languages of Europe*. Mouton de Gruyter: Berlin.

[3] Wagner, P. S. (2002). *Vorhersage und Wahrnehmung deutscher Betonungsmuster*. Doctoral Thesis, Rheinische-Friedrich-Wilhems Universität zu Bonn, http://hss.ulb.uni-bonn.de:90/ulb_bonn/diss_online/phil_fak/jahrgang_2002/wagner_petra_susanne

[4] Féry, C. (1998). *German Word Stress in Optimality Theory.* Rutgers Optimality Archive ROA 301-0399. http://ruccs.rutgers.edu/roa.html

[5] Lüngen, H. and D. Gibbon (2000). *Speech Lexica and Consistent Multilingual Vocabularies*. In: Wahlster, W. (ed.) *Verbmobil: Foundations of Speech-to-Speech Translation*, Berlin:Springer.

[6] Hain, H.-U. and H.G. Zimmermann (2001). *Optimierung der Eingabe eines neuronalen Netzes zur Bestimmung der Wortbetonung mit Hilfe von Weight Decay.* In: Hess, W. and K. Stöber (eds.): *Elektronische Sprachsignalverarbeitung*, Dresden, pp. 282-289.

[7] Mengel, A. (1998). *Deutscher Wortakzent. Symbole, Signale*. Phorm Verlag: München.

[8] Mengel, A. and A. Wirth (1995). *Lexikon deutscher Eigennamen.* CD-ROM. TU Berlin. Deutsche Telekom Technologiezentrum.

[9] Berg, T. (1997). Lexical Stress Differences in English and German: The special status of proper nouns. *Linguistische Berichte*, 167:3-22.

[10] Saha, A. (2003). *CTree Software for Excel*. http://www.geocities.com/adotsaha/ (25.02.2003).

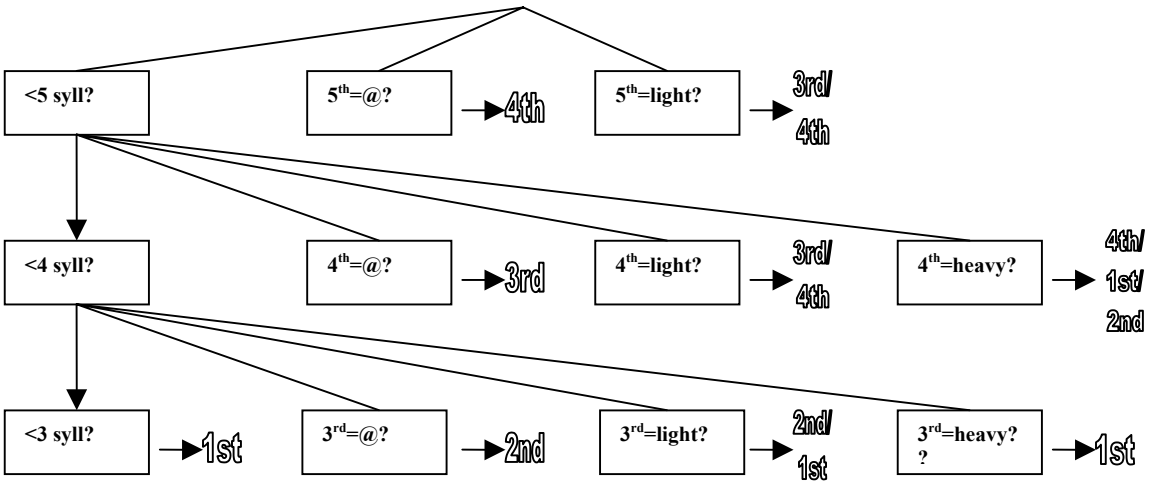

Figure 2: Simplified Classification Tree Predicting Stress of Proper Names. Predicted Numbers Represent the Number of the Syllable Within the Word.