

Summary of the M.Sc. thesis:

Automatic diagnosis and feedback for lexical stress errors in non-native speech

Towards a CAPT system for French learners of German

1 Introduction

The prosodic realization of lexical stress, the phenomenon by which certain syllable(s) in a word are accentuated more than others, is an important feature of the German phonological system, and may have a large impact on the intelligibility of non-native German speech (Hirschfeld, 1994). However, lexical stress can pose a considerable challenge to students learning German as a foreign language (L2), especially students whose native language (L1) is French (Hirschfeld and Trouvain, 2007). This thesis investigates how Computer Assisted Pronunciation Training (CAPT) can help L1 French speakers improve their lexical stress prosody in German. It describes the manual annotation of lexical stress errors in a small learner speech corpus, investigates a variety of methods for automatically diagnosing such errors in learner word utterances, and explores how these diagnoses can be used to deliver diverse types of feedback to learners. Its most important contribution is a prototype CAPT tool called **de-stress**: the German (**de**) System for **T**rainning and **R**esearch on **E**rrors in **S**econd-language **S**tress.¹ This tool integrates various diagnostic and feedback methods via an easy-to-use web interface (see fig. 1), and is designed not only to provide students with automatic, individualized feedback on their lexical stress errors, but also to facilitate future research on the efficacy of various diagnostic and feedback approaches.

¹github.com/vakila/de-stress

2 Lexical stress errors by French learners of German

In an effort to shed light on the nature of lexical stress errors in the speech of L1 French learners of German as L2, lexical stress realizations in utterances of bisyllabic, initial-stress words taken from the IFCASL corpus (Fauth et al., 2014; Trouvain et al., 2013) were annotated by native and non-native German annotators with various levels of phonetics/phonology expertise. Annotators labeled each word utterance as correctly or incorrectly realizing lexical stress (i.e. the speaker clearly stressed the correct or incorrect syllable), failing to clearly realize stress (i.e. the speaker did not seem to stress either syllable), or having technical or other problems which prevented the assessment of lexical stress.

Analysis of the labels assigned by different annotators to the same utterances revealed relatively low inter-annotator agreement; on average, pairs of annotators who labeled the same utterances agreed on 54.92% of utterances, and exhibited an average Cohen’s (1960) Kappa (κ) value of 0.23. Considerable variation was observed among individual annotators, which did not seem to be explained by differences in their L1 or level of phonetics/phonology expertise.

The multiple, often conflicting, error annotations from different annotators were consolidated into a single gold-standard annotation for each utterance in the dataset, which served as the basis for an analysis of the frequency and type of errors produced by learners. Overall, approximately two-thirds (63.77%) of learners’ utterances were deemed to realize lexical stress correctly, confirming that French learners of German frequently make errors with respect to lexical stress. The observed frequency of such errors was considerably lower in the speech of advanced learners than that of beginners, and children (ages 15-16) seemed to make more errors than adult beginners; no substantial difference was observed between speakers of different genders.

The error annotation and analysis described in this chapter thus contribute considerably to our understanding of the difficulties L1 French speakers may have realizing lexical stress in German, and the fact that learners, especially beginners and children, seem to struggle with lexical stress production justifies the selection of lexical stress errors as the focus of this thesis project. Additionally, the analysis of inter-annotator agreement presented

in this chapter, specifically the finding that the observed agreement was generally rather low, constitutes an important discovery with respect to the task of identifying such errors in learner speech: though further research is needed to determine why and under which conditions this is the case, it would seem that diagnosing lexical stress errors may be a challenging task for at least some L1 and L2 German speakers. If true, this has important implications for the development and evaluation of automatic error diagnosis systems, which is the subject of the following section.

3 Diagnosis of lexical stress errors

With the motivation of helping French learners of German correct these frequently-produced lexical stress errors, this thesis explores the methods by which such errors can be automatically diagnosed in learner speech. All diagnosis starts from a prosodic analysis of the learner’s utterance in terms of duration, fundamental frequency (F0), and intensity, i.e. the three acoustic properties most strongly correlated with the prosodic realization of lexical stress (see e.g. Cutler, 2005; Dogil and Williams, 1999), and whose perceptual correlates are timing, pitch, and loudness, respectively. This analysis requires reasonably accurate automatically-produced segmentations of the words, syllables, and phones of a given utterance; while forced alignment can theoretically be used to produce such segmentations on the fly when the text of the utterance is known (Mesbahi et al., 2011, e.g.), the current implementation of de-stress mocks the alignment step by using pre-existing automatic segmentations for the utterances from the IFCASL corpus (Fauth et al., 2014). Using these segmentations, features capturing the relative duration, F0, and intensity of each syllable in a given word utterance are automatically extracted using the speech processing functionality of the JSnoori software² (Di Martino and Laprie, 1999; Laprie, 1999).

Using these features to represent a given learner’s (L2) utterance as well as corresponding utterance(s) by L1 speakers, it is possible to assess the learner’s utterance via one of two primary strategies: comparison or classification. Diagnosis by comparison is the method most commonly used in past CAPT systems and research (see e.g. Bonneau and Colotte, 2011; Delmonte, 2011; Eskenazi, 2009). In the simplest comparison-based approach

²`jsnoori.loria.fr`

implemented in de-stress, features of the relevant segments of a learner’s utterance are compared to the analogous features in a single L1 (reference) utterance using JSnoori, and an error is diagnosed when the utterances differ considerably with respect to the relevant features. To reduce some of the risk of the diagnosis “over-fitting” to speaker- or utterance-dependent features of a single reference, de-stress can average the results of multiple one-on-one comparisons to produce a multiple-reference diagnosis; this is a relatively novel approach to comparison-based diagnosis. Another innovation of de-stress relates to the method of choosing the reference utterance(s) for a given learner utterance; though most existing CAPT systems require manual selection of reference utterances, previous research by Probst et al. (2002) suggests that using an intelligently-selected reference speaker can help learners improve their pronunciation. Therefore, de-stress also offers an automatic selection option in which the reference is selected by choosing the L1 speaker(s) whose voice most closely resembles that of the learner, in terms of F0 mean and range.

The second diagnosis strategy explored in this thesis, classification of errors using machine learning algorithms, is a more novel approach to lexical stress error identification in CAPT, in which a learner’s utterance is compared to the more abstract model of L1 speech represented by a classifier trained on a large number of L1 utterances. Although some work has been done on classifying lexical stress patterns in English (Kim and Beutnagel, 2011; Shahin et al., 2012), the classification experiments conducted in this work constitute the first known exploration of how, and how effectively, classification-based diagnosis can be used to identify (in)correct realizations of lexical stress in German. Experiments with different prosodic feature sets suggest that the features seemingly most useful for classification relate to the duration and F0 of the utterance(s), unsurprising considering that these have been shown to be most closely linked to lexical stress in German (Cutler, 2005; Dogil and Williams, 1999). Features capturing the word type of the utterance as well as the age, gender and proficiency level of the speaker were also found to be quite valuable for error classification; combining these features with all three prosodic feature types resulted in the highest overall accuracy observed on this dataset (71.87% accuracy, $\kappa = 0.34$). As the observed agreement between the classifier’s labels and the gold standard thus slightly exceeded the overall inter-annotator agreement observed when hu-

mans were asked to perform this error diagnosis task (see section 2), these results seem encouraging. Unsurprisingly, slightly lower accuracy was observed when classifying utterances of word types or speakers not represented in the training data; however, the fact that accuracy on unseen words still remained comparable to the human inter-annotator agreement statistics seems to confirm the expectation that classification-based diagnosis may be a useful way to create CAPT systems which are not limited to words/sentences for which recorded L1 utterances are available.

In the administrative interface to de-stress (see fig. 3), a researcher or instructor can choose between these various approaches for diagnosing lexical stress errors (see fig. 4). This modularity and flexibility enables de-stress to facilitate much needed future research exploring which diagnostic methods are most useful to which learners in which situations.

4 Feedback on lexical stress errors

Based on a diagnosis of the learner’s lexical stress error(s) via one of the methods described in the previous section, the CAPT tool developed in this work can automatically generate and present explicit and/or implicit feedback on these errors. As seen in fig. 1, implicit feedback may be delivered in the form of graphical abstractions of the prosodic features of each syllable in a given utterance, or via text stylization that uses font size to convey the most important acoustic correlate of lexical stress prosody, duration. Explicit feedback options include graphical “skill bars” informing learners of the correctness of their pronunciation with regard to duration (timing), F0 (pitch), and intensity (loudness), as well as verbal feedback on this information via a series of error/success messages (see fig. 2). Finally, as self-assessment is a valuable way for learners to give themselves feedback on their own performance and take autonomous control of their learning (Mehlhorn, 2005; Neri et al., 2002), an additional feedback option offers learners the opportunity to self-assess their pronunciation via a short questionnaire.

Thanks to its modular implementation of the various feedback types, in combination with a simple configuration interface that allows researchers and/or instructors to easily pick and choose from the available options (see fig. 5), de-stress is therefore a valuable platform for future empirical inves-

tigations into the impacts of these feedback types on the acquisition of L2 word prosody by L1 French learners of German. Much work remains to be done to determine which feedback types are most effective in which learning contexts; by presenting a tool to facilitate such research, ostensibly the first of its kind for this type of error and aimed at this group of learners, this thesis has thus made an important contribution towards a more detailed understanding of the relative efficacy of feedback types in CAPT.

5 Conclusion

This thesis thus presents original work taking steps towards the development of a comprehensive, intelligent CAPT system for French learners of German. Drawing from previous research on foreign-language pedagogy, phonetics/phonology, and speech technology, as well as original research on the frequency of lexical stress errors in learner speech and novel methods for diagnosing such errors, the de-stress system developed in this thesis project is the first known CAPT tool dedicated to helping L1 French speakers improve their realization of lexical stress in German, and to facilitating research on the use of automatic, individualized feedback to help learners correct such errors. Once more is known about which diagnosis and feedback methods should be used in which contexts, this tool could become a useful component of a fully-fledged intelligent CAPT system, in which models of relevant aspects of the learning context (e.g. the student's skill level, progress, or personal preferences) are used to automatically decide which modules of the tool to activate.

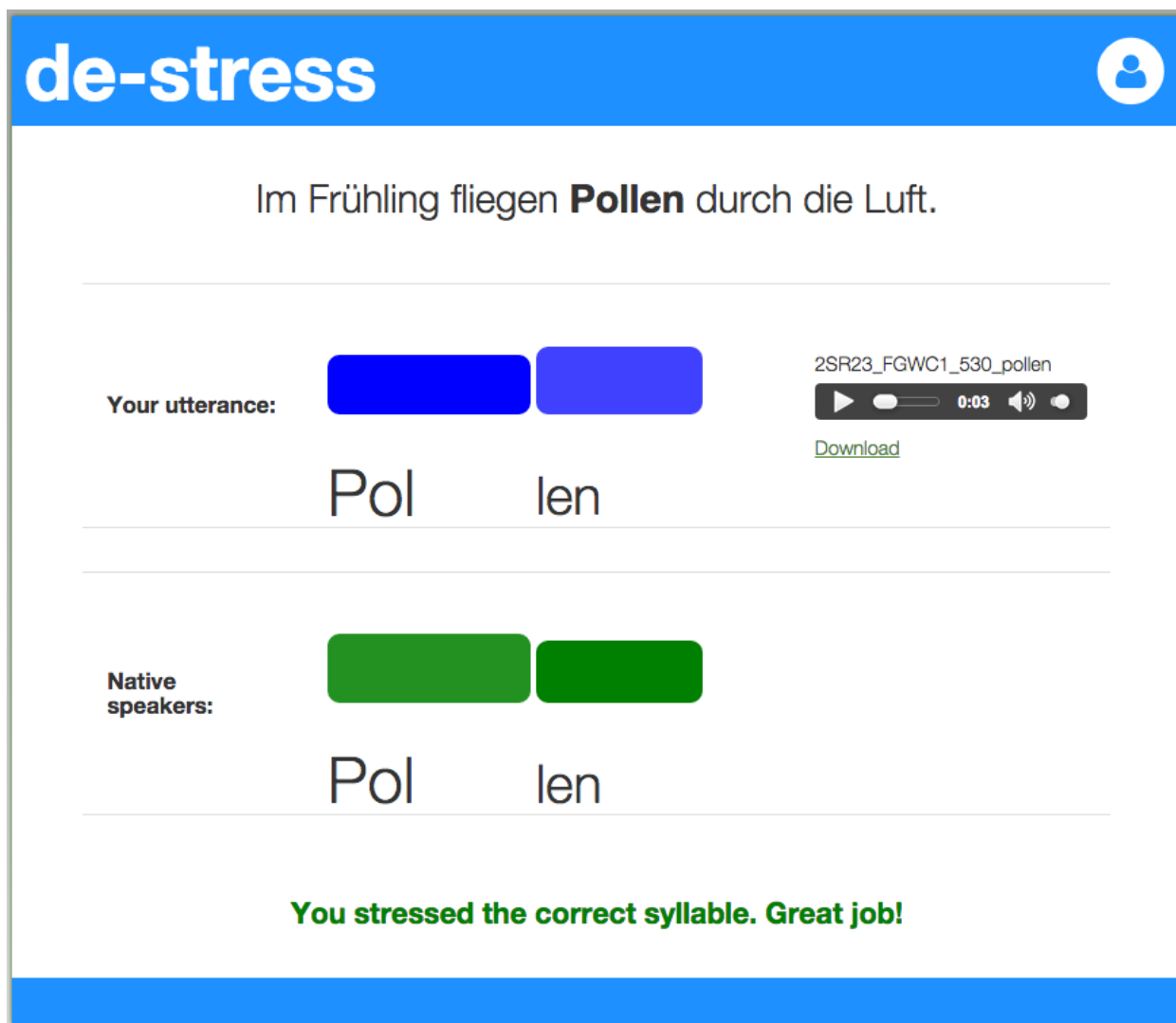


Figure 1: Screenshot of feedback delivery in the student-facing web interface of the prototype CAPT tool de-stress. The implicit feedback options depicted include graphical abstractions of prosody (the width, height, and opacity of each colored rectangle visualize the relative duration, mean F0, and mean intensity of the corresponding syllable) and text stylization (font size corresponds to duration).

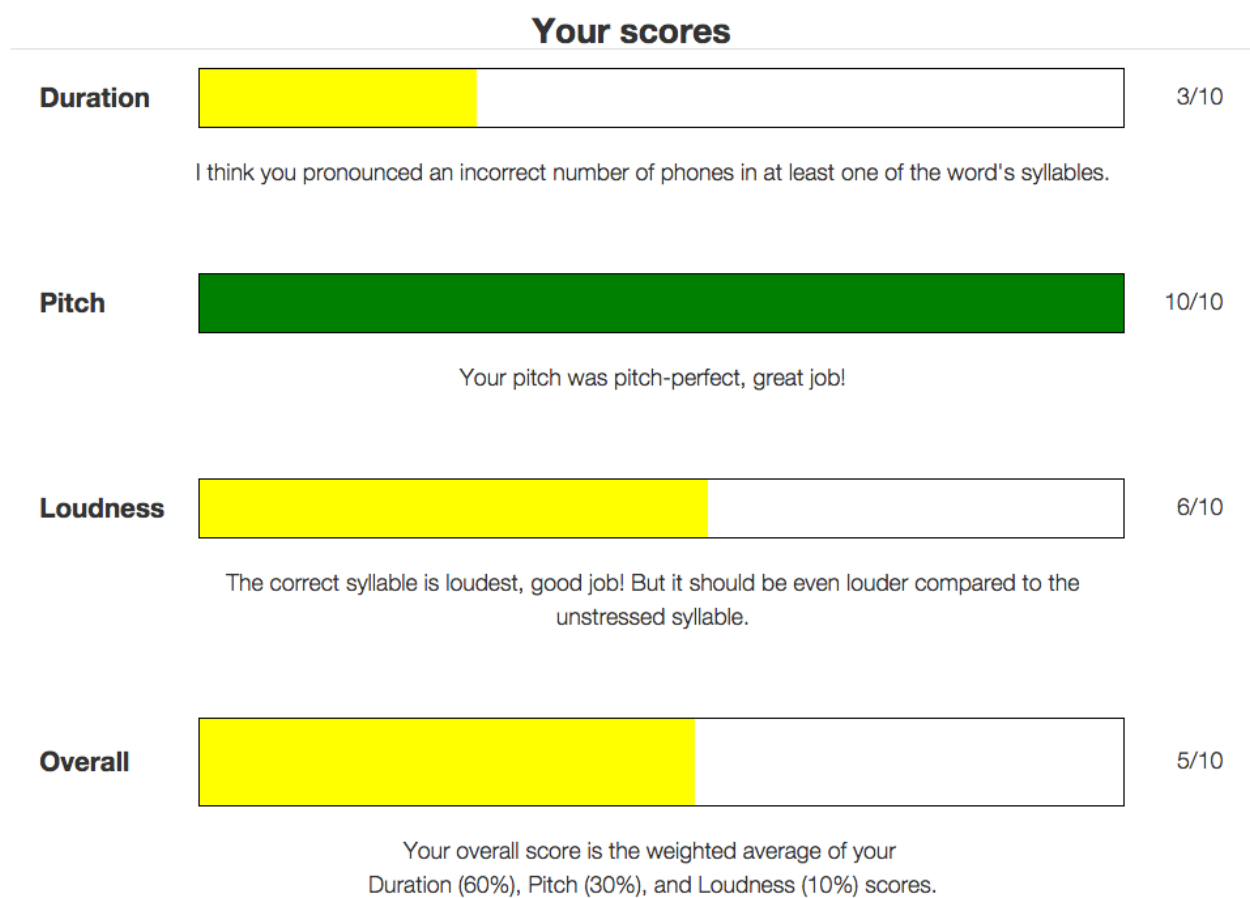



Figure 2: Explicit feedback options, including feedback via “skill bars” and via verbal error/success messages.

de-stress



[Home](#) [Exercise List](#)

Create Exercise

Name *

Description *

This exercise uses a simple one-on-one comparison method and delivers feedback via stylized text. Learners are asked to self-assess before feedback is delivered.

Word *

Diagnosis Method *

Feedback Method

Lessons


 Create

Figure 3: Screenshot of the administrative interface allowing a researcher or instructor to create an exercise utilizing certain diagnosis and feedback options (see figs. 4 and 5).

Create DiagnosisMethod

Name * SimpleComparison

Description Single ref. comparison

Scorer * Comparison ▾

Number Of References * 1

Selection Type MANUAL ▾


 Create

Figure 4: Administrative interface for selecting diagnosis options.

Create FeedbackMethod

Name * TextStylization-SelfAsses

Description

Requires Scorer Type ▾

Show Skill Bars ☐

Play Feedback Signal ☐

Display Shapes ☐

Style Text ☒

Display Messages ☐

Self Assessment ☒


 Create

Figure 5: Administrative interface for selecting feedback options.

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