

Automatic diagnosis and feedback for lexical stress errors in non-native speech: Towards a CAPT system for French learners of German

Anjana Sofia Vakil



UNIVERSITÄT
DES
SAARLANDES

Department of Computational Linguistics and Phonetics
University of Saarland, Saarbrücken, Germany

Master's Thesis Colloquium
16 April 2015

Some syllable(s) in a word more accentuated/prominent¹

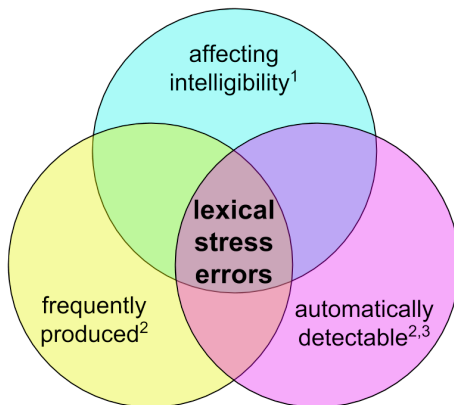
um·FAHR·en	vs.	UM·fahr·en
<i>to run over</i>		<i>to drive around</i>

- ▶ German: variable stress placement, contrastive stress¹
- ▶ French: no word-level stress, final syllable lengthening²

Goal: Computer-Assisted Pronunciation Training (CAPT) for lexical stress errors for French learners of German

¹A. Cutler. "Lexical Stress". In: *The Handbook of Speech Perception*. Ed. by D. B. Pisoni and R. E. Remez. 2005, pp. 264–289.

²M.-C. Michaux and J. Caspers. "The production of Dutch word stress by Francophone learners". In: *Proc. of the Prosody-Discourse Interface Conference (IDP)*. 2013, pp. 89–94.



¹U. Hirschfeld. *Untersuchungen zur phonetischen Verständlichkeit Deutschlernender*. Vol. 57. Forum Phonicum. 1994

²A. Bonneau and V. Colotte. "Automatic Feedback for L2 Prosody Learning". In: *Speech and Language Technologies*. Ed. by I. Ipsic. InTech, 2011

³Y.-J. Kim and M. C. Beutnagel. "Automatic assessment of American English lexical stress using machine learning algorithms". In: *SLaTE*. 2011, pp. 93–96

Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

Diagnosis methods

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

Feedback methods

de-stress: A prototype CAPT tool

Conclusion

Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

Diagnosis methods

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

Feedback methods

de-stress: A prototype CAPT tool

Conclusion

- ▶ *How reliably can human annotators identify errors in learner utterances?*
- ▶ *How frequently are errors actually produced by French learners of German?*

Data: IFCASL corpus of French-German speech¹

- ▶ German utterances by French and German speakers
 - Adults (>18) and children (15-16)
 - Levels A2, B1, B2, C1 (children all A2/B1)
- ▶ Word- and phone-level segmentations
(syllable level added automatically)
- ▶ Selected 12 word types (bisyllabic, initial stress)

Dataset for annotation:

668 German word utterances by ~55 French speakers

¹C. Fauth et al. “Designing a Bilingual Speech Corpus for French and German Language Learners: a Two-Step Process”. In: *9th Language Resources and Evaluation Conference (LREC)*. Reykjavik, Iceland, 2014, pp. 1477–1482.

15 Annotators, varying by:

- ▶ Native language (L1):
 - 12 German
 - 2 English (US)
 - 1 Hebrew
- ▶ Phonetics/phonology expertise:
 - 2 Experts
 - 10 Intermediates
 - 3 Novices

15 Annotators, varying by:

- ▶ Native language (L1):
 - 12 German
 - 2 English (US)
 - 1 Hebrew
- ▶ Phonetics/phonology expertise:
 - 2 Experts
 - 10 Intermediates
 - 3 Novices

Task: label utterances of 3 word types

15 Annotators, varying by:

- ▶ Native language (L1):
 - 12 German
 - 2 English (US)
 - 1 Hebrew
- ▶ Phonetics/phonology expertise:
 - 2 Experts
 - 10 Intermediates
 - 3 Novices

Task: label utterances of 3 word types

Praat annotation tool:

tragen
526

play word

play sentence

stress is on CORRECT syllable

stress is on INCORRECT syllable

no clear stress / I can't tell

wrong number of syllables

problem with audio

15 Annotators, varying by:

- ▶ Native language (L1):
 - 12 German
 - 2 English (US)
 - 1 Hebrew
- ▶ Phonetics/phonology expertise:
 - 2 Experts
 - 10 Intermediates
 - 3 Novices

Task: label utterances of 3 word types

Praat annotation tool:

tragen
526

play word

play sentence

stress is on CORRECT syllable [correct]

stress is on INCORRECT syllable [incorrect]

no clear stress / I can't tell [none]

wrong number of syllables [bad_nsylls]

problem with audio [bad_audio]

How reliably can human annotators identify errors in learner utterances?

- ▶ Agreement calculated for each pair of annotators who labeled the same utterances
- ▶ Quantified by:
 - Percentage agreement: $N_{\text{agreed}}/N_{\text{both annotated}}$
 - Cohen's Kappa¹ (κ): accounts for chance agreement

¹J. Cohen. "A Coefficient of Agreement for Nominal Scales". In: *Educational and Psychological Measurement* 20.1 (Apr. 1960), pp. 37–46.

Overall pairwise agreement between annotators

	% Agreement	Cohen's κ
Mean	54.92%	0.23
Maximum	83.93%	0.61
Median	55.36%	0.26
Minimum	23.21%	-0.01

¹J. R. Landis and G. G. Koch. "The measurement of observer agreement for categorical data." In: *Biometrics* 33.1 (1977), pp. 159–174.

Overall pairwise agreement between annotators

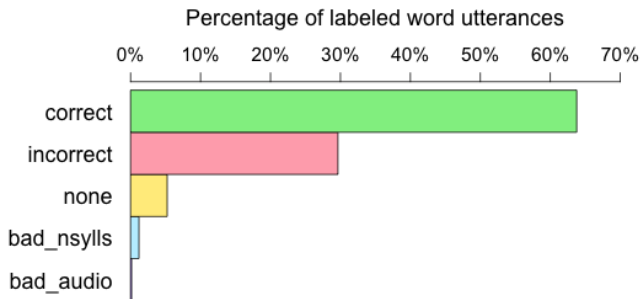
	% Agreement	Cohen's κ
Mean	54.92%	0.23
Maximum	83.93%	0.61
Median	55.36%	0.26
Minimum	23.21%	-0.01

- ▶ Rather low agreement (“fair”¹ mean κ)
- ▶ Large variability among annotators, not explained by L1/expertise
- ▶ Single gold-standard label selected for each utterance

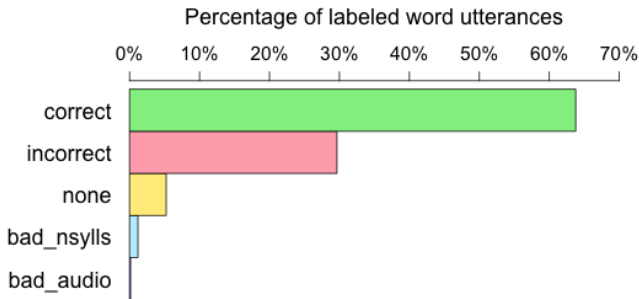
¹J. R. Landis and G. G. Koch. “The measurement of observer agreement for categorical data.” In: *Biometrics* 33.1 (1977), pp. 159–174.

How frequently are errors actually produced by French learners of German?

How frequently are errors actually produced by French learners of German?



How frequently are errors actually produced by French learners of German?



- ▶ Large variability across word types
- ▶ Beginners made more errors (vs. advanced)
- ▶ Children made more errors (vs. adult beginners)

Lexical stress errors by French learners of German

Annotation of a learner speech corpus

Inter-annotator agreement

Frequency & distribution of errors

Diagnosis methods

Word prosody analysis

Diagnosis by comparison

Diagnosis by classification

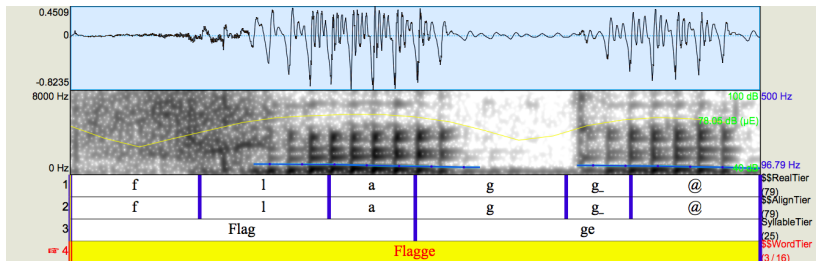
Feedback methods

de-stress: A prototype CAPT tool

Conclusion

Requires word, syllable, and phone segmentations

- ▶ Automatically produced via forced alignment¹
- ▶ This work uses existing IFCASL segmentations
- ▶ Syllable segmentations derived from words & phones



¹L. Mesbahi et al. "Reliability of non-native speech automatic segmentation for prosodic feedback." In: *SLaTE*. 2011.

Duration (DUR)

- ▶ Perceptual correlate: length/timing
- ▶ Best indicator of German stress¹
- ▶ Simple to extract from segmentations
- ▶ Features: Relative syllable & nucleus (vowel) lengths

¹G. Dogil and B. Williams. “The phonetic manifestation of word stress”. In: *Word Prosodic Systems in the Languages of Europe*. Ed. by H. van der Hulst. Berlin: Walter de Gruyter, 1999. Chap. 5, pp. 273–334.

Fundamental frequency (F0)

- ▶ Perceptual correlate: pitch
- ▶ 2nd best indicator of stress after duration¹
- ▶ Pitch contours computed using JSnoori^{2,3}
- ▶ Features: relative syllable & nucleus:
 - Mean F0 (in voiced segments)
 - Maximum F0
 - Minimum F0
 - F0 range (max–min)

¹G. Dogil and B. Williams. “The phonetic manifestation of word stress”. In: *Word Prosodic Systems in the Languages of Europe*. Ed. by H. van der Hulst. Berlin: Walter de Gruyter, 1999. Chap. 5, pp. 273–334.

²jsnoori.loria.fr

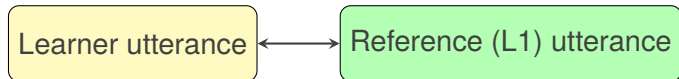
³J. Di Martino and Y. Laprie. “An efficient F0 determination algorithm based on the implicit calculation of the autocorrelation of the temporal excitation signal”. In: *EUROSPEECH*. Budapest, Hungary, 1999, p. 4.

Intensity (INT)

- ▶ Perceptual correlate: loudness
- ▶ Worse predictor than DUR or F0, but still may have effect on stress perception¹
- ▶ Energy contours computed using Jsnoori
- ▶ Features: relative syllable & nucleus:
 - Mean energy (over 60dB “silence threshold”)
 - Maximum energy

¹A. Cutler. “Lexical Stress”. In: *The Handbook of Speech Perception*. Ed. by D. B. Pisoni and R. E. Remez. 2005, pp. 264–289.

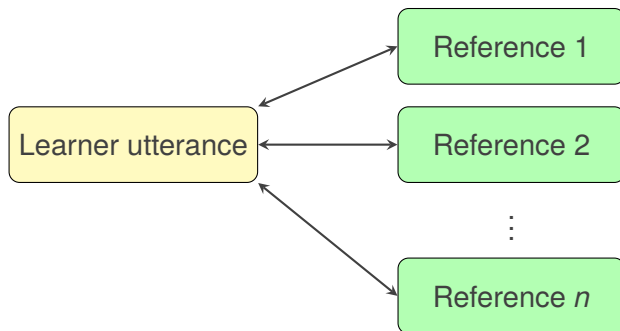
Comparison to a single reference utterance



- ▶ Simplest approach, common in CAPT
- ▶ JSnoori (and predecessors) use this method¹
 - Assigns 3 scores (DUR, F0, INT)
 - ▶ Same syllable stressed?
 - ▶ Difference between stressed/unstressed syllables similar enough?
 - Overall score = weighted average of 3 scores
- ▶ Problem: extremely utterance-dependent!

¹A. Bonneau and V. Colotte. "Automatic Feedback for L2 Prosody Learning". In: *Speech and Language Technologies*. Ed. by I. Ipsic. InTech, 2011.

Comparison to multiple reference utterances



- ▶ Less common in CAPT systems
- ▶ Less utterance-dependent than single comparison
- ▶ Overall score = average of one-on-one scores

Options for selecting reference speaker(s)

- ▶ Manually
 - Learner's choice
 - Teacher/researcher's choice
- ▶ Automatically
 - May be more effective to choose reference speaker most closely resembling the learner¹
 - Selected by comparing speakers' F0 mean and range (using all available recordings)

¹K. Probst et al. "Enhancing foreign language tutors - In search of the golden speaker". In: *Speech Communication* 37.3-4 (July 2002), pp. 161–173.

- ▶ More abstract representation of L1 pronunciation
- ▶ Not yet explored for German CAPT

Research questions:

- ▶ *How well can lexical stress errors be classified?*
- ▶ *How does that compare with human agreement?*
- ▶ *Which features are most useful for classification?*

Experiments:

- ▶ Trained CART classifiers using WEKA toolkit¹
- ▶ Used error-annotated dataset for training/test data (gold-standard labels)
- ▶ Used L1 utterances of the same words as training data (all automatically labeled [correct])

Evaluated in terms of:

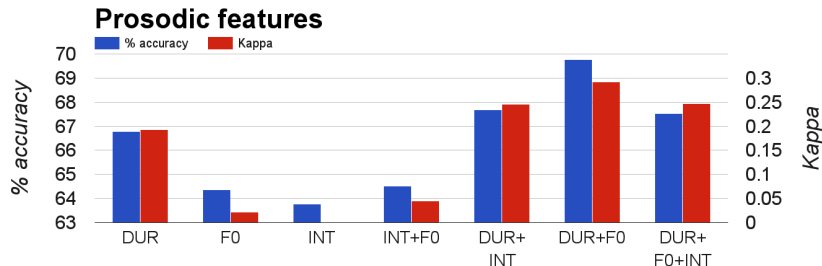
- ▶ % accuracy (% agreement with gold-standard labels)
- ▶ κ with respect to gold standard

¹www.cs.waikato.ac.nz/ml/weka

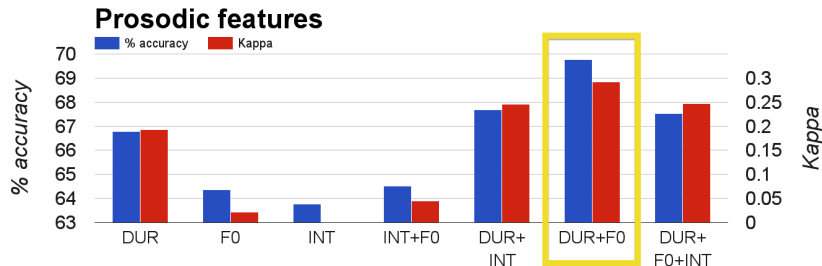
Which features are most useful for classification?

Feature set	Description
DUR	Duration features
F0	Fundamental frequency features
INT	Intensity features
WD	Uttered word (e.g. <i>Tatort</i>)
LV	Speaker's skill level (A2 B1 B2 C1)
AG	Speaker's age/gender (Girl Boy Woman Man)

How well can lexical stress errors be classified?



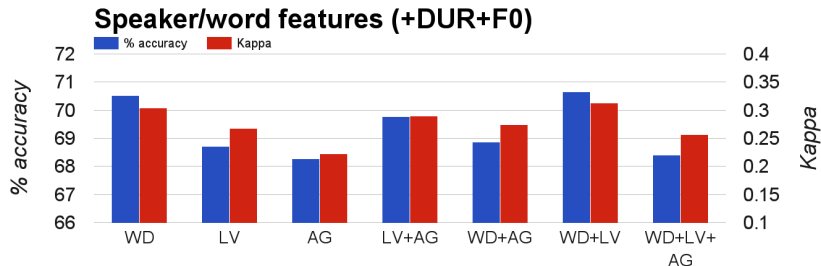
How well can lexical stress errors be classified?



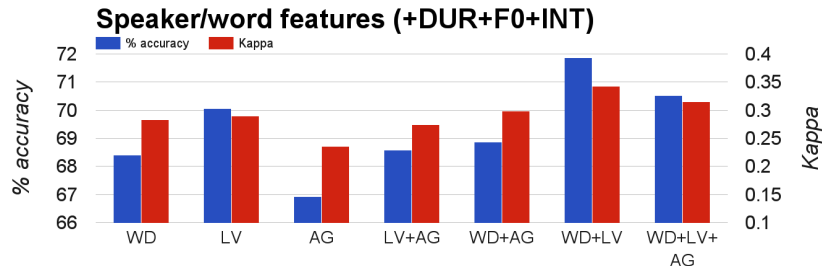
Best performance using only prosodic features: DUR+F0

- ▶ % Accuracy: 69.77%
- ▶ κ : 0.29

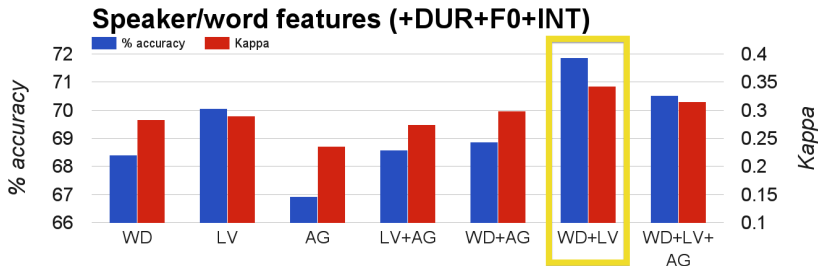
How well can lexical stress errors be classified?



How well can lexical stress errors be classified?



How well can lexical stress errors be classified?



Best performance overall: WD+LV+DUR+F0+INT

- ▶ % Accuracy: 71.87%
- ▶ κ : 0.34

How does classification accuracy compare with human agreement?

	% agreement	κ
Best classifier vs. gold standard	71.87%	0.34
Mean human vs. human	54.92%	0.23

- ▶ Results are encouraging in this context
- ▶ Still want better performance for real-world use

Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

Diagnosis methods

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

Feedback methods

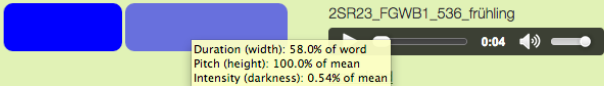
de-stress: A prototype CAPT tool

Conclusion

Allows learner to notice features of their utterance/reference utterance, without explicitly evaluating their pronunciation

Im **Frühling** fliegen Pollen durch die Luft.

Your utterance:



2SR23_FGWB1_536_frühling

Duration (width): 58.0% of word
Pitch (height): 100.0% of mean
Intensity (darkness): 0.54% of mean

Früh ling

Reference utterance 1:



2SR23_GGMC1_034_frühling

[Download](#)

Früh ling

Directly calls learner's attention to error(s) and/or offers corrective instruction

Your scores

Duration



3/10

I think you pronounced an incorrect number of phones in at least one of the word's syllables.

Pitch



10/10

Your pitch was pitch-perfect, great job!

Loudness



6/10

The correct syllable is loudest, good job! But it should be even louder compared to the unstressed syllable.

Overall



5/10

Your overall score is the weighted average of your
Duration (60%), Pitch (30%), and Loudness (10%) scores.

May be linked to progress and motivation¹

Self-assessment

Listen to your utterance and the reference utterance(s).

Then answer these questions:

Which syllable did you stress?

- ☐ The first syllable (correct)
- ☐ The second syllable (incorrect)
- ☐ Neither syllable (incorrect)

Is the stress as clear in your utterance as it is in the reference utterance?

- ☐ Just as clear as in reference
- ☐ Not as clear as in reference
- ☐ I don't know

What could you work on for next time?

Continue

¹A. Neri et al. "The pedagogy-technology interface in computer assisted pronunciation training". In: *Computer Assisted Language Learning* (2002).

Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

Diagnosis methods

- Word prosody analysis

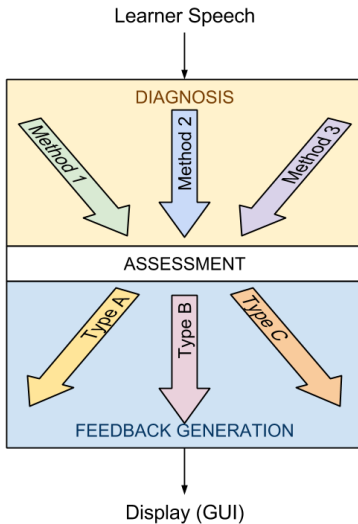
- Diagnosis by comparison

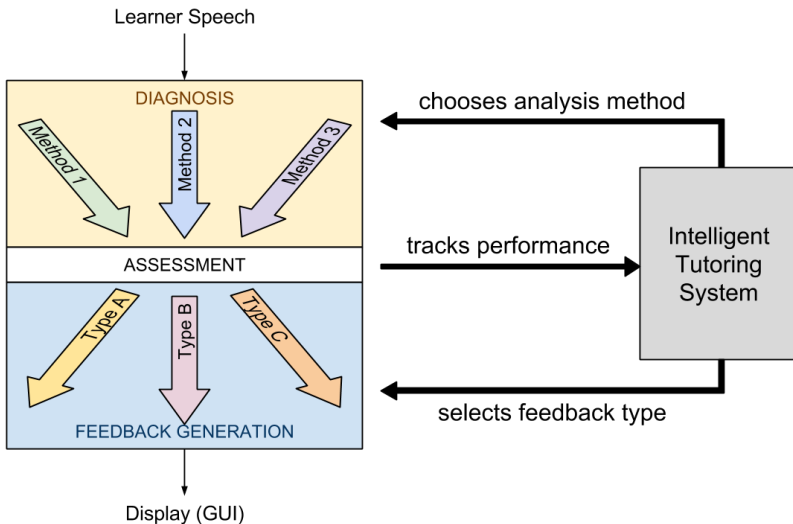
- Diagnosis by classification

Feedback methods

de-stress: A prototype CAPT tool

Conclusion





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](#)

Create DiagnosisMethod

Name * SimpleComparison

Description Single ref. comparison

Scorer * Comparison

Number Of
References *

1

Selection Type MANUAL

 Create

Create FeedbackMethod

Name * TextStylization-SelfAsses

Description

Requires Scorer Type

Show Skill Bars

Play Feedback Signal

Display Shapes

Style Text

Display Messages

Self Assessment

 Create

de-stress

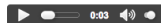


Im Frühling fliegen **Pollen** durch die Luft.

Your utterance:



2SR23_FGWC1_530_pollen



[Download](#)

Pol len

Native
speakers:



Pol len

You stressed the correct syllable. Great job!

Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

Diagnosis methods

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

Feedback methods

de-stress: A prototype CAPT tool

Conclusion

Main contributions of the thesis:

Main contributions of the thesis:

- ▶ Annotation & analysis of lexical stress errors in small corpus of German spoken by French speakers
 - Rather low inter-annotator agreement
 - Roughly one-third of utterances contained errors

Main contributions of the thesis:

- ▶ Annotation & analysis of lexical stress errors in small corpus of German spoken by French speakers
 - Rather low inter-annotator agreement
 - Roughly one-third of utterances contained errors
- ▶ Exploration of classification for error diagnosis
 - 71.87% accuracy, $\kappa = 0.34$ wrt. gold-standard labels
 - Slightly better than mean inter-annotator agreement

Main contributions of the thesis:

- ▶ Annotation & analysis of lexical stress errors in small corpus of German spoken by French speakers
 - Rather low inter-annotator agreement
 - Roughly one-third of utterances contained errors
- ▶ Exploration of classification for error diagnosis
 - 71.87% accuracy, $\kappa = 0.34$ wrt. gold-standard labels
 - Slightly better than mean inter-annotator agreement
- ▶ The de-stress CAPT tool
 - Integrates various diagnosis and feedback methods
 - Allows teachers/researchers control over methods used

Main contributions of the thesis:

- ▶ Annotation & analysis of lexical stress errors in small corpus of German spoken by French speakers
 - Rather low inter-annotator agreement
 - Roughly one-third of utterances contained errors
- ▶ Exploration of classification for error diagnosis
 - 71.87% accuracy, $\kappa = 0.34$ wrt. gold-standard labels
 - Slightly better than mean inter-annotator agreement
- ▶ The de-stress CAPT tool
 - Integrates various diagnosis and feedback methods
 - Allows teachers/researchers control over methods used

Future work:

- ▶ In vivo studies using de-stress
- ▶ Improve classification performance (e.g. new algorithms)

- ▶ A. Cutler. "Lexical Stress". In: *The Handbook of Speech Perception*. Ed. by D. B. Pisoni and R. E. Remez. 2005, pp. 264–289
- ▶ M.-C. Michaux and J. Caspers. "The production of Dutch word stress by Francophone learners". In: *Proc. of the Prosody-Discourse Interface Conference (IDP)*. 2013, pp. 89–94
- ▶ U. Hirschfeld. *Untersuchungen zur phonetischen Verständlichkeit Deutschlernender*. Vol. 57. Forum Phonetikum. 1994
- ▶ A. Bonneau and V. Colotte. "Automatic Feedback for L2 Prosody Learning". In: *Speech and Language Technologies*. Ed. by I. Ipsic. InTech, 2011
- ▶ Y.-J. Kim and M. C. Beutnagel. "Automatic assessment of American English lexical stress using machine learning algorithms". In: *SLaTE*. 2011, pp. 93–96
- ▶ C. Fauth et al. "Designing a Bilingual Speech Corpus for French and German Language Learners: a Two-Step Process". In: *9th Language Resources and Evaluation Conference (LREC)*. Reykjavik, Iceland, 2014, pp. 1477–1482
- ▶ G. Dogil and B. Williams. "The phonetic manifestation of word stress". In: *Word Prosodic Systems in the Languages of Europe*. Ed. by H. van der Hulst. Berlin: Walter de Gruyter, 1999. Chap. 5, pp. 273–334
- ▶ J. Di Martino and Y. Laprie. "An efficient F0 determination algorithm based on the implicit calculation of the autocorrelation of the temporal excitation signal". In: *EUROSPEECH*. Budapest, Hungary, 1999, p. 4
- ▶ K. Probst et al. "Enhancing foreign language tutors - In search of the golden speaker". In: *Speech Communication* 37.3-4 (July 2002), pp. 161–173
- ▶ A. Neri et al. "The pedagogy-technology interface in computer assisted pronunciation training". In: *Computer Assisted Language Learning* (2002)

Many thanks to:

- ▶ DFG/ANR Project IFCASL
- ▶ Bernd Möbius
- ▶ Jürgen Trouvain
- ▶ Yves Laprie
- ▶ Julie Busset
- ▶ Frank Zimmerer
- ▶ Jeanin Jügler