

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

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Some syllable(s) in a word more accentuated/prominent<sup>1</sup>

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

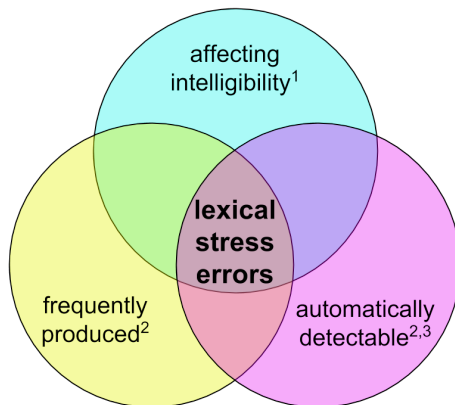
- ▶ German: variable stress placement, contrastive stress<sup>1</sup>
- ▶ French: no word-level stress, final syllable lengthening<sup>2</sup>

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

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

<sup>2</sup>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.



<sup>1</sup>U. Hirschfeld. *Untersuchungen zur phonetischen Verständlichkeit Deutschlernender*. Vol. 57. Forum Phonicum. 1994

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

<sup>3</sup>Y.-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

- ▶ *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 speech<sup>1</sup>

- ▶ 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

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<sup>1</sup>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.

15 Annotators, varying by:

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

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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

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tragen  
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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 Kappa<sup>1</sup> ( $\kappa$ ): accounts for chance agreement

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<sup>1</sup>J. 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 $\kappa$
Mean	54.92%	0.23
Maximum	83.93%	0.61
Median	55.36%	0.26
Minimum	23.21%	-0.01

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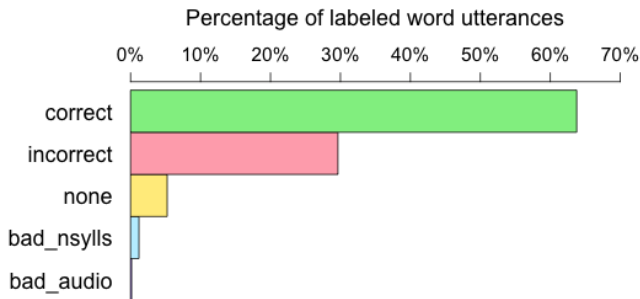
- ▶ Rather low agreement (“fair”<sup>1</sup> mean  $\kappa$ )
- ▶ Large variability among annotators, not explained by L1/expertise
- ▶ Single gold-standard label selected for each utterance

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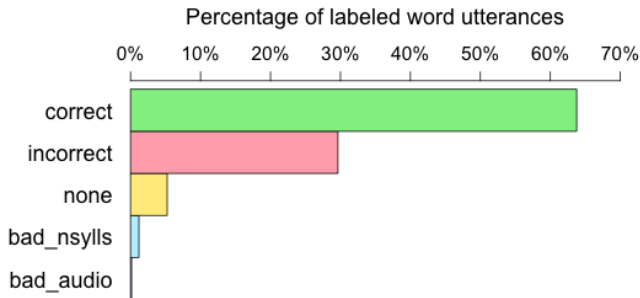
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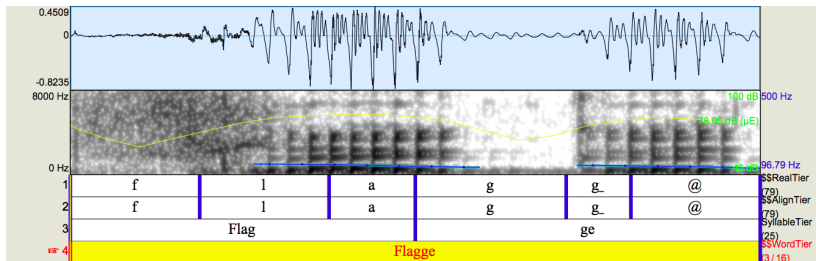


- ▶ Large variability across word types
- ▶ Beginners made more errors (vs. advanced)
- ▶ Children made more errors (vs. adult beginners)



Requires word, syllable, and phone segmentations

- ▶ Automatically produced via forced alignment<sup>1</sup>
- ▶ This work uses existing IFCASL segmentations
- ▶ Syllable segmentations derived from words & phones



<sup>1</sup>L. 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 stress<sup>1</sup>
- ▶ Simple to extract from segmentations
- ▶ Features: Relative syllable & nucleus (vowel) lengths

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<sup>1</sup>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.

## Fundamental frequency (F0)

- ▶ Perceptual correlate: pitch
- ▶ 2nd best indicator of stress after duration<sup>1</sup>
- ▶ Pitch contours computed using JSnoori<sup>2,3</sup>
- ▶ Features: relative syllable & nucleus:
  - Mean F0 (in voiced segments)
  - Maximum F0
  - Minimum F0
  - F0 range (max–min)

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<sup>1</sup>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.

<sup>2</sup>[jsnoori.loria.fr](http://jsnoori.loria.fr)

<sup>3</sup>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.

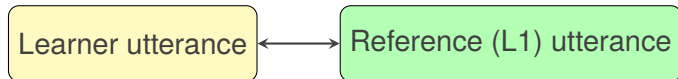
## Intensity (INT)

- ▶ Perceptual correlate: loudness
- ▶ Worse predictor than DUR or F0, but still may have effect on stress perception<sup>1</sup>
- ▶ Energy contours computed using Jsnoori
- ▶ Features: relative syllable & nucleus:
  - Mean energy (over 60dB “silence threshold”)
  - Maximum energy

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<sup>1</sup>A. 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

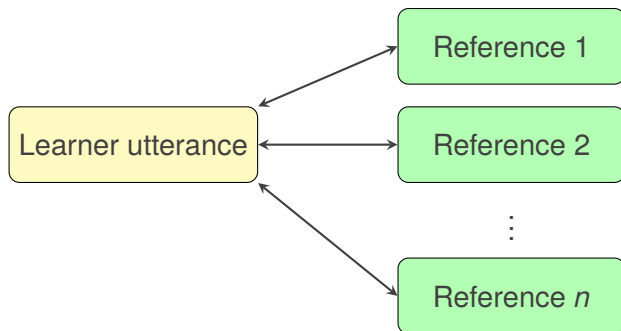


- ▶ Simplest approach, common in CAPT
- ▶ JSnoori (and predecessors) use this method<sup>1</sup>
  - Assigns 3 scores (DUR, F0, INT)
    - ▶ Same syllable stressed?
    - ▶ Difference between stressed/unstressed syllables similar enough?
  - Overall score = weighted average of 3 scores
- ▶ Problem: extremely utterance-dependent!

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## 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 learner<sup>1</sup>
- Selected by comparing speakers' F0 mean and range (using all available recordings)

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<sup>1</sup>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.

- ▶ 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 toolkit<sup>1</sup>
- ▶ 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)
- ▶  $\kappa$  with respect to gold standard

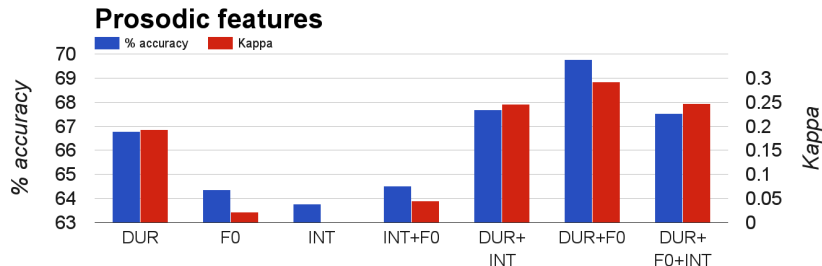
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<sup>1</sup>[www.cs.waikato.ac.nz/ml/weka](http://www.cs.waikato.ac.nz/ml/weka)

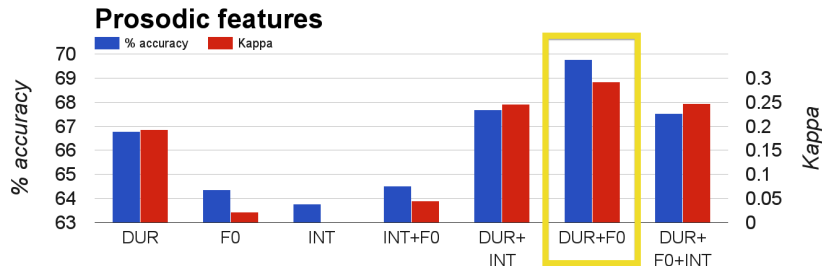
*Which features are most useful for classification?*

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?*



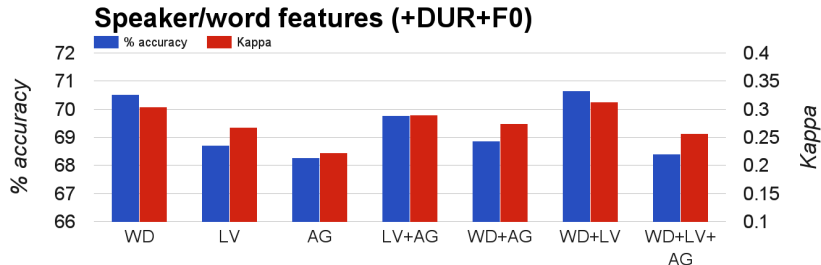
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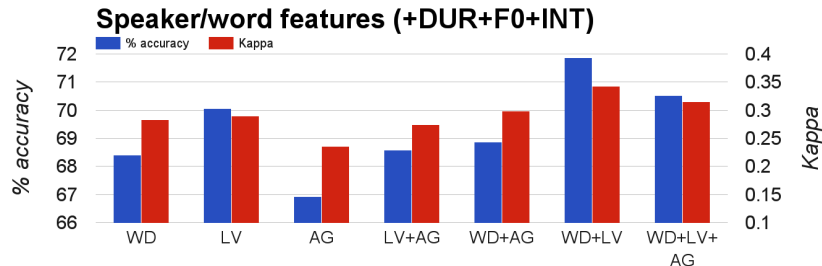
Best performance using only prosodic features: DUR+F0

- ▶ % Accuracy: 69.77%
- ▶  $\kappa$ : 0.29

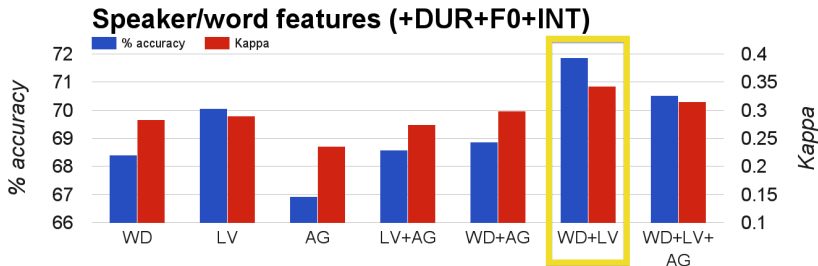
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*How well can lexical stress errors be classified?*



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

- ▶ % Accuracy: 71.87%
- ▶  $\kappa$ : 0.34

*How does classification accuracy compare with human agreement?*

	% agreement	$\kappa$
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



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

0:04

Früh ling

Reference utterance 1:



2SR23\_GGMC1\_034\_frühling

0:03

[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 motivation<sup>1</sup>

## 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?

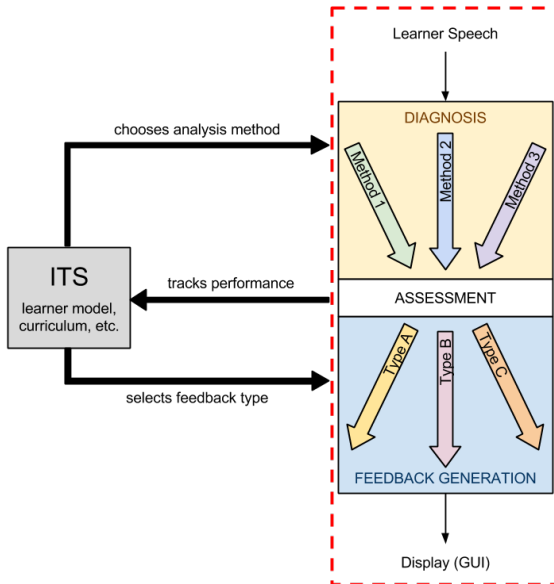
- ☐ Just as clear as in reference
- ☐ Not as clear as in reference
- ☐ I don't know

### What could you work on for next time?

Continue

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



## de-stress



Home



Exercise List

### Create Exercise

Name \* Comparison-StyleText

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 \* fliegen

Diagnosis Method

\* SimpleComparison-1refs-MANUAL

Feedback Method

TextStylization-SelfAssessed

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

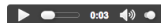


Im Frühling fliegen **Pollen** durch die Luft.

Your utterance:



2SR23\_FGWC1\_530\_pollen



[Download](#)

Pol len

Native  
speakers:



Pol len

**You stressed the correct syllable. Great job!**

Main contributions of the thesis:



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- ▶ Annotation & analysis of lexical stress errors in small corpus of German spoken by French speakers
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## Future work:

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