

# 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.

## Motivation

### Lexical stress errors by French learners of German

- Annotation of a learner speech corpus

- Inter-annotator agreement

- Frequency & distribution of errors

## Diagnosis

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

## Feedback

- Implicit

- Explicit

- Self-assessment

## The de-stress CAPT tool

Figure: Criteria for selecting errors to target in a CAPT system.



Lexical stress errors seem to be:

- ▶ Frequently produced by French learners of variable-stress languages<sup>1,2</sup>
- ▶ More important for intelligibility in L2 German than other types of errors<sup>3</sup>
- ▶ Possible to identify automatically by comparison<sup>1</sup> or classification<sup>4</sup>

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<sup>1</sup>A. Bonneau and V. Colotte. “Automatic Feedback for L2 Prosody Learning”. In: *Speech and Language Technologies*. Ed. by I. Ipsic. InTech, 2011.

<sup>2</sup>M.-C. Michaux. “Exploring the production and perception of word stress by French-speaking learners of Dutch”. In: *Workshop on Crosslinguistic Influence in Non-Native Language Acquisition*. 2012.

<sup>3</sup>U. Hirschfeld. *Untersuchungen zur phonetischen Verständlichkeit Deutschlernender*. Vol. 57. Forum Phonetikum. 1994.

<sup>4</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.

- ▶ 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 L1/L2 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 word utterances by 55-56 L1 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: **[TODO make this a matrix?]**

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

**[TODO 5 labels, remove the below]**

Each annotated 3 word types in one ~15 min. session  
(1 annotator did 6 word types in 2 sessions)



Figure: 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

Figure: Praat annotation tool

tragen  
526

play word

play sentence

[correct]	stress is on CORRECT syllable
[incorrect]	stress is on INCORRECT syllable
[none]	no clear stress / I can't tell
[bad_nsylls]	wrong number of syllables
[bad_audio]	problem with audio

*How reliably can human annotators identify errors in learner utterances?*

- ▶ Agreement calculated for each overlapping pair
- ▶ Quantified by:
  - Percentage agreement:  $N_{\text{agreed}}/N_{\text{both annotated}}$
  - Cohen's Kappa<sup>1</sup> ( $\kappa$ ): accounts for chance agreement
- ▶ **[TODO remove?]** Overall agreement represented by mean, minimum, median, and maximum of all pairwise values

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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.

**Table:** 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

- ▶ Rather low agreement (“fair”<sup>1</sup> mean  $\kappa$ )
- ▶ Large variability between annotators
- ▶ Not explained by L1/expertise groups

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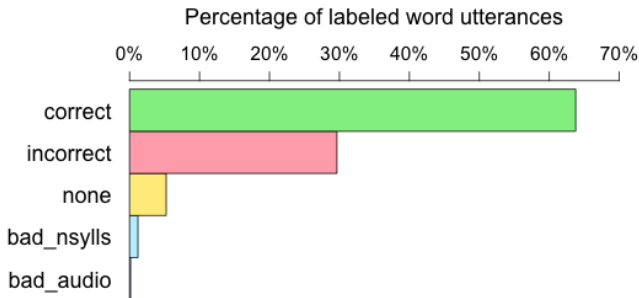
<sup>1</sup>J. R. Landis and G. G. Koch. “The measurement of observer agreement for categorical data.” In: *Biometrics* 33.1 (1977), pp. 159–174.

## [TODO Find more graphical way to portray this? Remove?]

Need a single label for each utterance to analyze error frequency & evaluate automatic diagnosis

- ▶ 268 utterances: no disagreement
- ▶ 265 utterances: majority vote
- ▶ remaining 135 utterances decided by rules, e.g.:
  - favor Expert judgments
  - favor certainty ([correct],[incorrect]) over [none]
  - be generous to learners if [correct] vs. [incorrect]

*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)

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

**[TODO segmentation screenshot]**

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<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.

**[TODO Slide previewing comparison vs. classification?]**

## Comparison to a single reference utterance

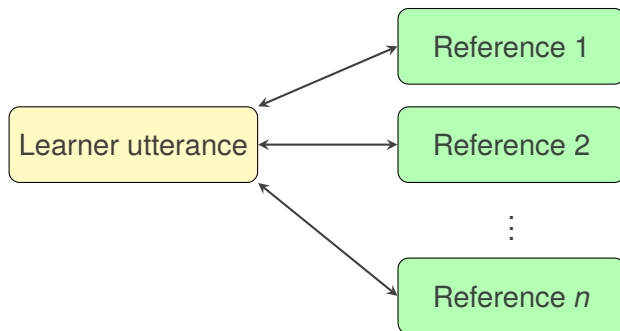


- ▶ Simplest approach, common in CAPT
- ▶ JSnoori (and predecessors) use this method<sup>1</sup>
  - Assigns 3 scores (DUR, F0, INT)
    - ▶ Same syllable stressed?
    - ▶ Difference between stressed/unstressed syllables similar enough?
  - Overall score = weighted average of 3 scores
- ▶ Problem: extremely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

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<sup>1</sup>A. 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 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 annotated L2 dataset for training/test data
- ▶ Used L1 utterances of the same words as training data (all automatically labeled [correct])

## Evaluated in terms of:

- ▶ Agreement ( $\%$ ,  $\kappa$ ) with gold-standard labels
- ▶ Precision, Recall,  $F_1$  and  $F_2$  for [correct] class **[TODO explain and/or put on handout]**

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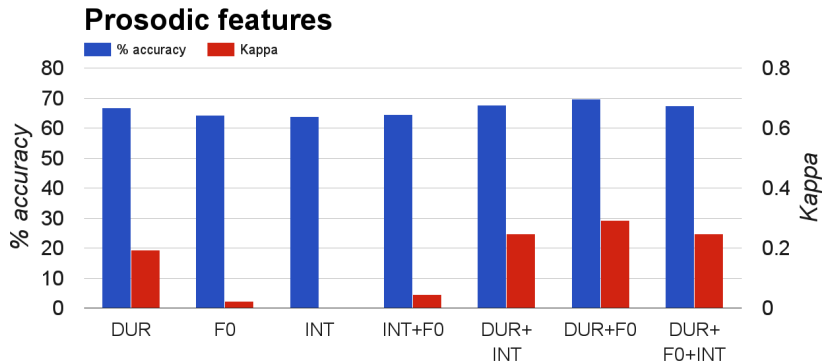
<sup>1</sup>[www.cs.waikato.ac.nz/ml/weka](http://www.cs.waikato.ac.nz/ml/weka)



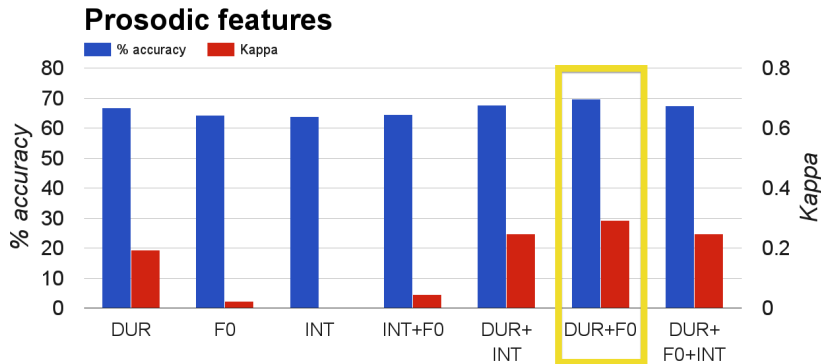
*Which features are most useful for classification?*

Feature set	Description
DUR	Duration features
F0	Fundamental frequency features
INT	Intensity features
WD	Uttered word (e.g. <i>Tatort</i> )
LV	Speaker's L2 German skill level (A2 B1 B2 C1)
AG	Speaker's age/gender (Girl Boy Woman Man)

*How well can lexical stress errors be classified?*



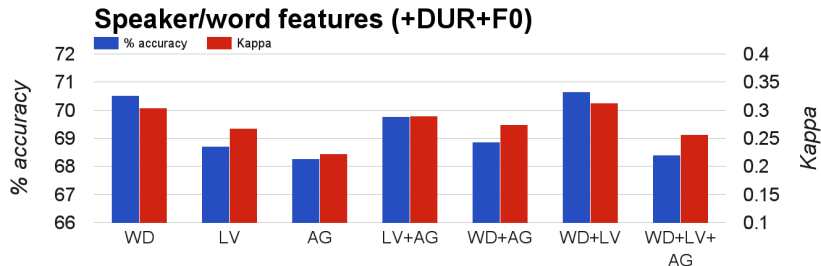
*How well can lexical stress errors be classified?*



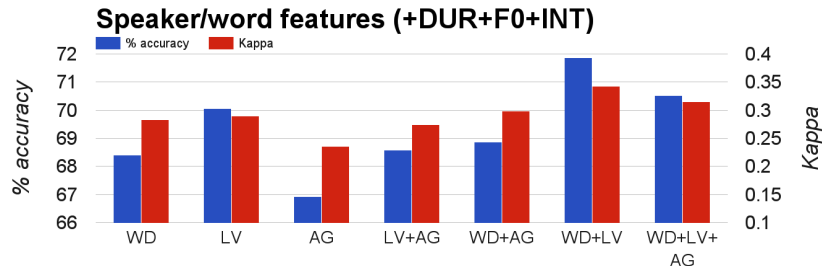
Best performance using only prosodic features: DUR+F0

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

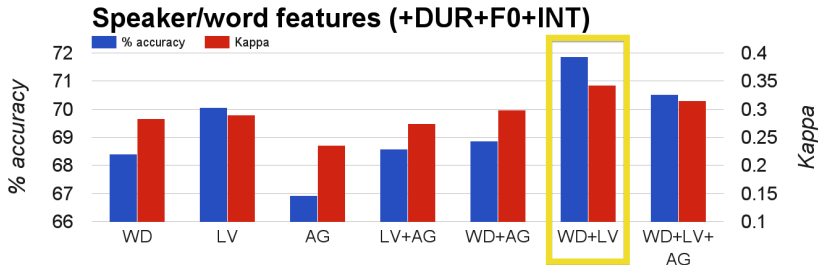
*How well can lexical stress errors be classified?*



*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%
- ▶  $\kappa$ : 0.34

**[TODO ]**

**[TODO ]**



**[TODO ]**

- ▶ Create Exercise
- ▶ Create DM
- ▶ Create Scorer?
- ▶ Create FM
- ▶ Show FB output