

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/prominent¹

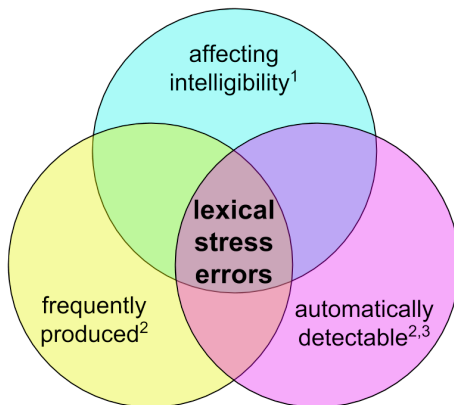
um·FAHR·en	vs.	UM·fahr·en
<i>to run over</i>		<i>to drive around</i>

- ▶ 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

- Word prosody analysis

- Diagnosis by comparison

- Diagnosis by classification

Feedback

- Implicit

- Explicit

- Self-assessment as feedback

The de-stress 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 L1/L2 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 word utterances by 55-56 L1 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: **[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 Kappa¹ (κ): accounts for chance agreement
- ▶ **[TODO remove?]** Overall agreement represented by mean, minimum, median, and maximum of all pairwise values

¹J. 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 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 between annotators
- ▶ Not explained by L1/expertise groups

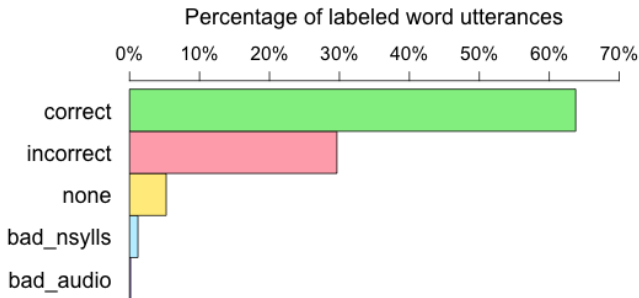
¹J. R. Landis and G. G. Koch. “The measurement of observer agreement for categorical data.” In: *Biometrics* 33.1 (1977), pp. 159–174.

[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 alignment¹
- ▶ This work uses existing IFCASL segmentations
- ▶ Syllable segmentations derived from words & phones

[TODO segmentation screenshot]

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.

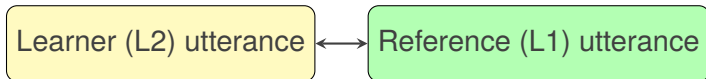
Intensity (INT)

- ▶ 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.

[TODO Slide previewing comparison vs. classification?]

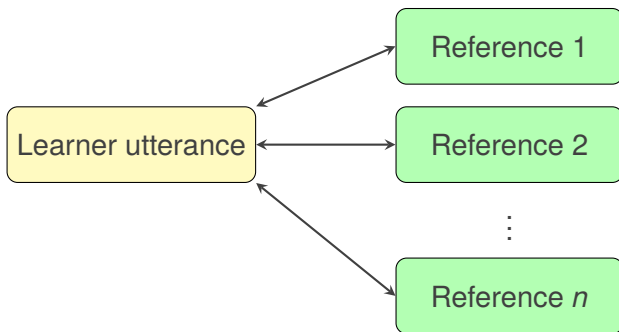
Comparison to a single reference utterance



- ▶ 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 annotated L2 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:

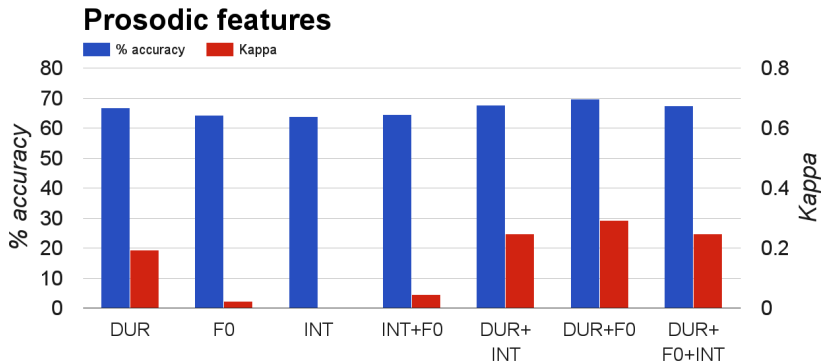
- ▶ Agreement ($\%$, κ) with gold-standard labels
- ▶ Precision, Recall, F_1 and F_2 for [correct] class **[TODO explain and/or put on handout]**

¹www.cs.waikato.ac.nz/ml/weka

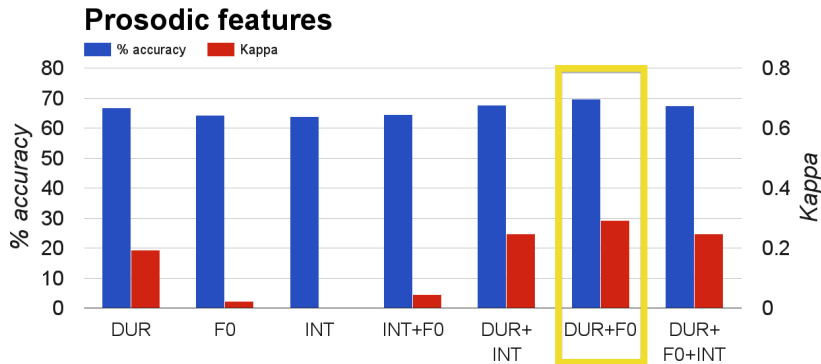
Which features are most useful for classification?

Feature set	Description
DUR	Duration features
F0	Fundamental frequency features
INT	Intensity features
WD	Uttered word (e.g. <i>Tatort</i>)
LV	Speaker's 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?



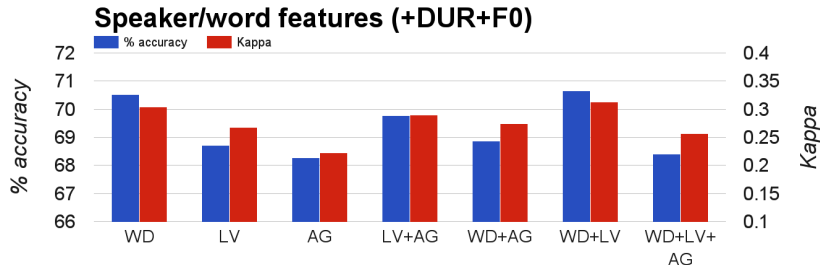
How well can lexical stress errors be classified?



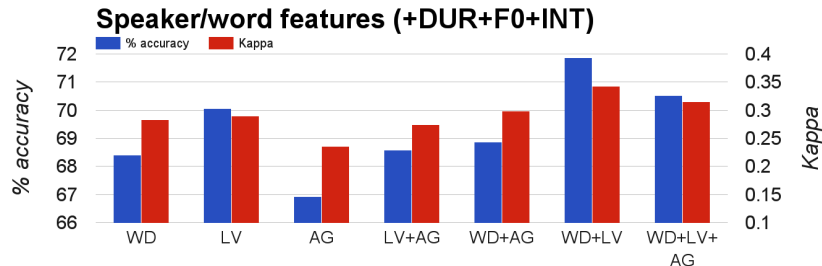
Best performance using only prosodic features: DUR+F0

- ▶ % Accuracy: 69.77%
- ▶ κ : 0.29

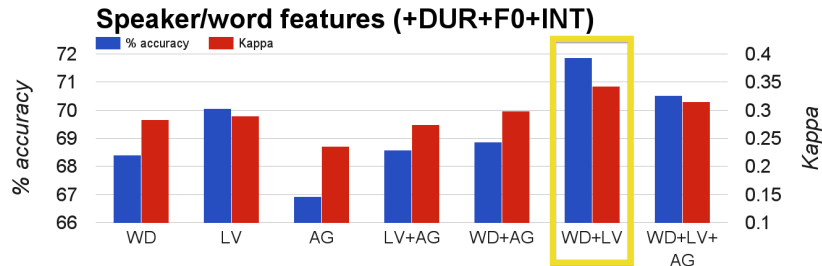
How well can lexical stress errors be classified?



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

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 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)

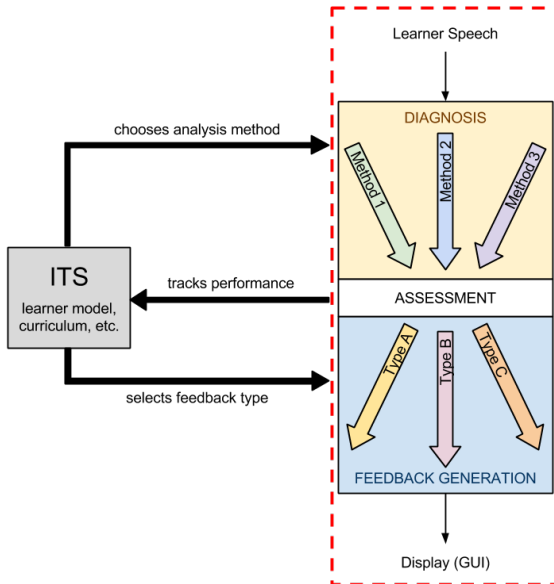
Is the stress as clear in your utterance as it is in the reference utterance?

- ☐ 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).



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

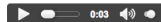


Im Frühling fliegen **Pollen** durch die Luft.

Your utterance:



2SR23_FGWC1_530_pollen



[Download](#)

Pol len

Native
speakers:



Pol len

You stressed the correct syllable. Great job!

[TODO]