

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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Master's Thesis Colloquium
16 April 2015

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

um·FAHR·en vs. UM·fahr·en
to run over *to drive around*

- ▶ 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.

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^{1,2}
- ▶ More important for intelligibility in L2 German than other types of errors³
- ▶ Possible to identify automatically by comparison¹ or classification⁴

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

²M.-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.

³U. Hirschfeld. *Untersuchungen zur phonetischen Verständlichkeit Deutschlernender*. Vol. 57. Forum Phonetikum. 1994.

⁴Y.-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 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

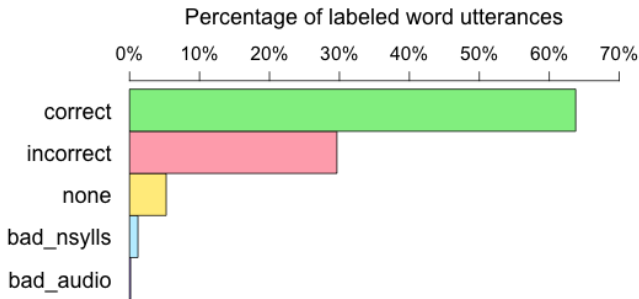
¹J. R. Landis and G. G. Koch. “The measurement of observer agreement for categorical data.” In: *Biometrics* 33.1 (1977), pp. 159–174.

[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?]

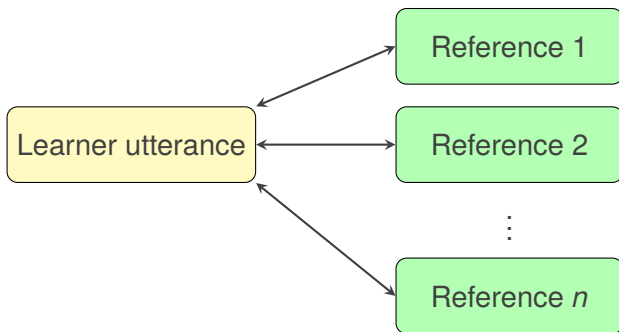
Comparison to a single reference utterance



- ▶ 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
- ▶ Used L1 utterances of the same words as training data (all automatically labeled [correct])

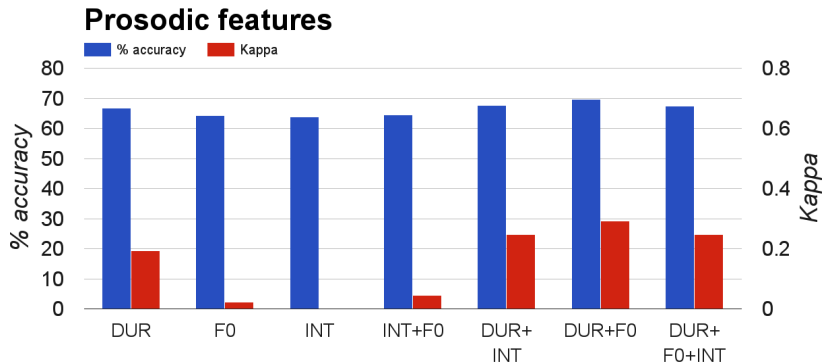
Evaluated in terms of:

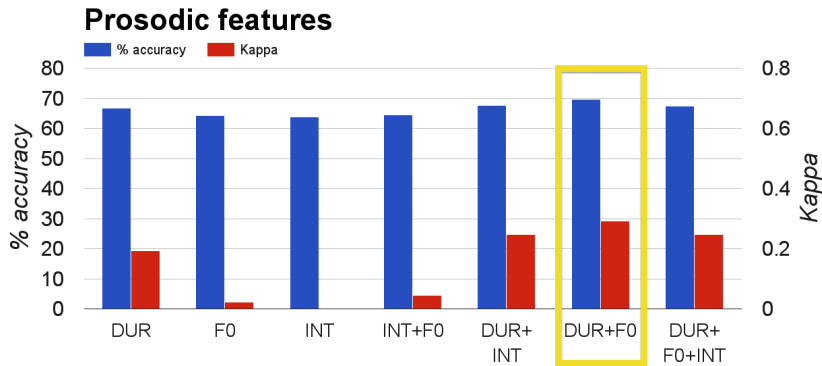
- ▶ Agreement ($\%$, κ) with gold-standard labels
- ▶ Precision, Recall, F_1 and F_2 for [correct] class **[TODO explain and/or put on handout]**

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)





Best performance using only prosodic features: DUR+F0

- ▶ % Accuracy: 69.77%
- ▶ κ : 0.29

[TODO]

[TODO]

[TODO]

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