Acoustic and articulatory manifestations of final lengthening and voicing contrasts for German learners of English as a second language

Oxana Rasskazova [1], Malte Belz [1], Christine Mooshammer [1,2], Jelena Krivokapić [2,3]

[1] Humboldt-Universität zu Berlin, Germany
[2] Haskins Laboratories, USA
[3] University of Michigan, USA

oxana.rasskazova@hu-berlin.de, malte.belz@hu-berlin.de

Abstract

The present acoustic and articulatory study investigates whether German native speakers show prosodic and segmental transfer effects of the L1 when speaking English as L2. The focus lies on prosodic lengthening patterns as well as voicing contrast in word-final position in English, a pattern that is difficult for many German learners due to their native syllable-final obstruent devoicing rule.

Index Terms: prosody, final lengthening, final devoicing, English as a second language

1. Introduction

Most segments show temporal variation for prosodic changes, see [1, 2, 3, 4]. For example, there are indications that consonants as well as vowels tend to be longer at prosodic boundaries than phrase-medially, e.g., [5, 6]. However, different segments and segment classes are not always affected in a uniform way. For example, [7] and [8] show that tense but not lax vowels in German stretch in stressed syllables and compress for fast speech rate.

In our previous acoustic and articulatory studies [9, 10], we investigated the effects of phrasal boundaries on the temporal characteristics of preceding segments in German as well the interaction of tenseness and final lengthening. The results show that, contrary to speech rate and stress effects, lax vowel in phrase-final position lengthen, although less than tense vowels. The articulatory closing gesture for consonants as well as the duration of constriction phase is longer for phrase-final compared to phrase-medial position.

In the present production study we will investigate two aspects that might contribute to a pronounced L2 accent: In our first experiment we will focus on whether German native speakers deviate from their lengthening patterns found for German when speaking English. Both, English and German show final lengthening effects, but it is unclear whether lengthening also interacts with tenseness. As a null hypothesis, we expect that subjects show the same prosodic features as in German when speaking English, e.g., lax vowels will show a lengthening effect in phrase-final positions, but less than tense vowels (Hypothesis 1).

Furthermore, we are interested in whether German native speakers transfer the phonological pattern of word-final obstruent devoicing into English or whether they produce a voicing contrast in word-final positions. [11] found that some acoustic patterns of L1 German, such as consonant closure durations for voiceless versus voiced obstruents, were transferred to L2 English, whereas other acoustic parameters correspond to phonological patterns typical for English, such as longer vowel durations before voiced obstruents. However, the interaction between tenseness of the preceding vowel and post-vocalic voicing was not addressed in [11]. Since lax vowels are temporally more inflexible in German than in English [7] we assume that there will be a stronger transfer of German word-final obstruent devoicing for words with lax vowels than for words with tense vowels (Hypothesis 2). We investigate whether German native speakers neutralize voiced word-final consonants in English by means of acoustic as well as articulatory data.

2. Method

2.1. Speakers and Stimuli

Acoustic and articulatory data of 8 native German participants were recorded in a sound proof cabin by means of EMA (AG 501, Carstens Electronics). Sensors were attached to tongue tip, mid and back, the jaw, the lips and four reference sensors for compensating for head movements. The speakers (4 male, 4 female) are 23–28 years old and advanced English learners. German and English sentences with target words containing minimal pairs differing in vowel tenseness and consonant voicing were presented on a monitor, with 5 repetitions, respectively. Target sentences were presented in a random order and mixed with filler sentences. The target words were embedded in two boundary strength contexts: phrase-medial (1) and phrase-final (2), e.g.:

(1) We should wait for a ***beat*** in any event. I wouldn´t know when to start.

(2) We should wait for a ***beat***. In any event, I wouldn´t know when to start.

For a comparison of the lengthening effect in L1 German and L2 English, we compared the minimal pairs *beat/bit* and *Beet/Bett* (Engl. ‘bed’ (botan.), ‘bed’). For the voicing contrast part, we analyzed the English minimal pairs *beat/bead, bit/bid, seat/seed*, and *sit/Sid*.

2.2. Analysis

Tongue tip movements were labelled for the closing gesture duration towards alveolar consonants and closure duration in the target word using *mview* (Mark Tiede, Haskins Laboratories). Closing duration is defined as the time span of closing movement onset and plateau onset for the word-final consonant by using a 20% threshold criterion based on the tangential velocity of the tongue tip signal. Closed phase duration is defined as the time span between plateau onset and plateau offset.

The acoustic measurements of vowel duration preceding voiced and voiceless consonants, consonant closure duration, duration of voicing into closure and VOT was carried out in Praat [12]. All statistics were carried out using R 3.3.0 [13] with the packages lme4 [14] and lmerTest [15].

3. Results

3.1. Comparing final lengthening in L1 German and L2 English for German native speakers

To analyze whether German native speakers exhibit the same degree of final lengthening for the minimal pairs *beat/bit* and *Beet/Bett*, we calculated a linear mixed-effect model for acoustic vowel duration (logarithmic) with target language (German vs. English), tenseness (tense vs. lax), and phrasal condition (medial vs. final) and their interactions as fixed effects and participants as random effects (cf. Fig. 1). Significant differences are found for phrase-final vs. phrase-medial position ($\beta = .33$, se = .03, $p < .001$), for English vs. German targets ($\beta = .19$, se = .03, $p < .001$), and for tense vs. lax vowels ($\beta = .58$, se = .03, $p < .001$), as well as for the interaction of position and vowel ($\beta = -.17$, se = .04, $p < .001$).

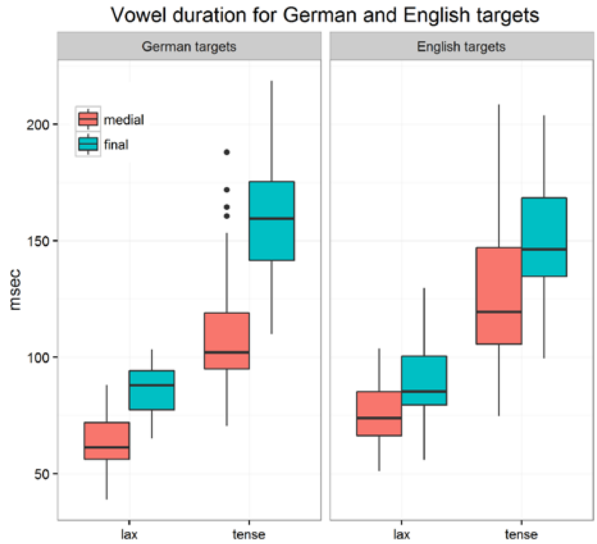

Figure 1: *The effect of tenseness and phrasal condition on acoustic vowel duration in L1 (German,* Beet/Bett*) and L2 (English,* beat/bit*). Red (left) boxes represent targets in phrase-medial position; blue (right) boxes represent targets in phrase-final position.*

The same minimal pairs are also analyzed for the articulatory consonant closing and plateau duration. We calculated a mixed-effect model with the same fixed and random effects structure as for vowel duration. For logarithmic closing duration, no significant effect is found for phrase-final position or tenseness. However, English targets exhibit a significant longer closing duration than German targets ($\beta = .58$, se = .04, $p < .001$), cf. Fig. 2. The interaction between position and tenseness is significant ($\beta = .3$, se = .06, $p < .01$), because closing duration only lengthens following tense vowels in final position.

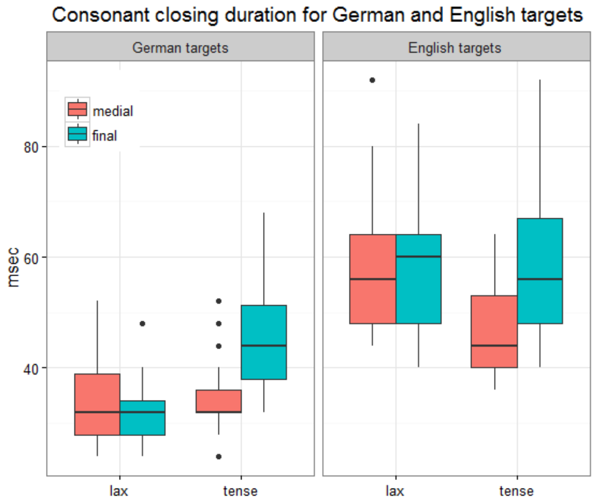

Figure 2: *The effect of tenseness and phrasal condition on articulatory consonant closing duration in L1 (German,* Beet/Bett*) and L2 (English* beat/bit*). Red (left) boxes represent targets in phrase-medial position; blue (right) boxes represent targets in phrase-final position*

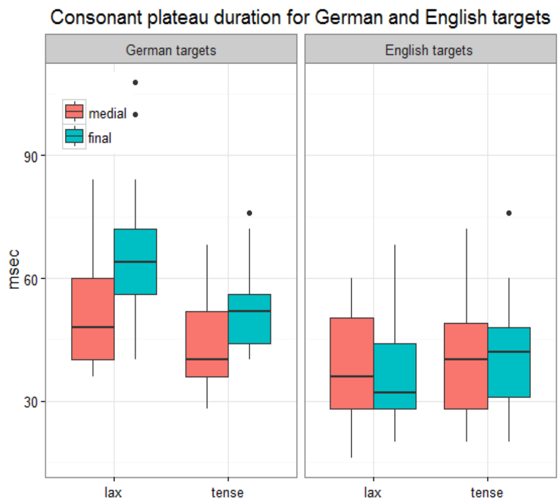

Figure 3: *The effect of tenseness and phrasal condition on articulatory consonant plateau duration in L1 (German,* Beet/Bett*) and L2 (English,* beat/bit*). Red (left) boxes represent targets in phrase-medial position; blue (right) boxes represent targets in phrase-final position.*

The model for consonant plateau duration (cf. Fig. 3) displays a significant effect on plateau duration for phrase-final position ($\beta = .21$, se = .05, $p < .001$). Plateau duration of English targets is significantly smaller than for German targets ($\beta = -.38$, se =.05, $p < .001$). Closures following tense vowels are significantly shorter than following lax vowels ($\beta = -.17$, se = .05, $p < .01$). For English targets in phrase-final position the plateau duration is significantly smaller than for the corresponding German targets ($\beta = -.21$, se = .08, $p < .05$). The interaction between targets and tenseness is significant ($\beta = .28$, se = 07, p < .001), as plateau duration for English targets shows no effects of tenseness and position.

3.2. Voicing contrast in L2 (English)

To investigate whether German subjects produce a voicing contrast in word-final positions when speaking L2 English, we analyzed the acoustic measures vowel duration preceding voiced vs. unvoiced consonants, consonant closure duration, duration of voicing into closure and VOT and the articulatory measures consonant closing and plateau duration.

A linear mixed-effects model for vowel duration on a logarithmic scale with phrasal condition, tenseness and voicing as well as their interactions as fixed effects, and targets as well as subjects with random slopes for voicing as random effects reveals significant main effects of (phrase-final) condition ($\beta = .28$, se = 3.5, $p < .001$) and tense vowels ($\beta = .48$, se = .03, $p < .001$), but not for voiced vs. voiceless consonants and for none of the interactions (cf. Fig. 4).

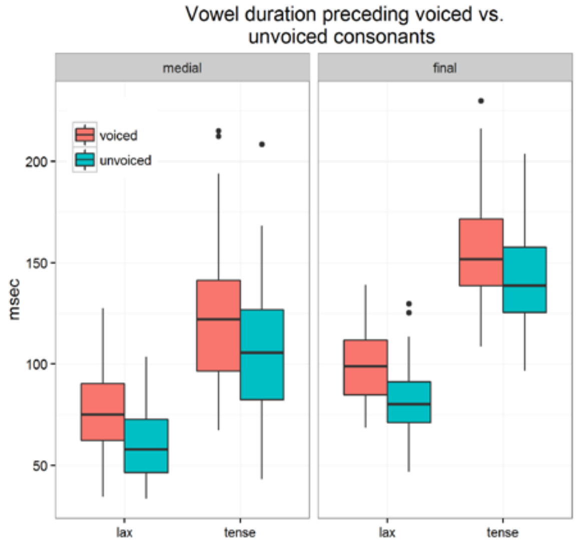

Figure 4: *Lax vs. tense acoustic vowel duration preceding voiced vs. unvoiced consonants in phrase-medial vs. phrase-final position. Red (left) boxes represent voiced targets; blue (right) boxes represent unvoiced targets.*

Logarithmic closing duration show a significant final lengthening effect ($\beta = .16$, se = .03, $p < .001$). There are no significant main effects of tenseness and voicing, but a three-way interaction of tenseness, position, and voicing ($\beta = .17$, se = .07, $p < .05$, cf. Fig. 5).

Logarithmic plateau duration show no main effects for voicing, tenseness or position. There is a three-way interaction of phrase-final position, preceding tense vowel, and voiced consonant targets ($\beta = -.27$, se = .13, $p < .05$).

For the acoustic measures during the stops, the logarithmic duration of voicing during consonant closure (cf. the red bars in Fig 6) is shorter for unvoiced targets ($\beta = -.26$, se = .07, $p < .001$). This effect is enhanced in final positions ($\beta = -.26$, se = .1, $p < .05$).

The logarithmic acoustic closure duration (cf. the green bars in Fig. 6) is longer in phrase-final position ($\beta = .26$, se =09, $p < .01$) and smaller for tense compared to lax vowels ($\beta = -.5$, se = .1, $p > .001$). There are interactions of position and tenseness ($\beta = .44$, se = .13, $p < .01$) and of tenseness and voicing ($\beta = .36$, se = .13, $p < .01$) because no voicing contrast is found for consonants following lax vowels in medial position.

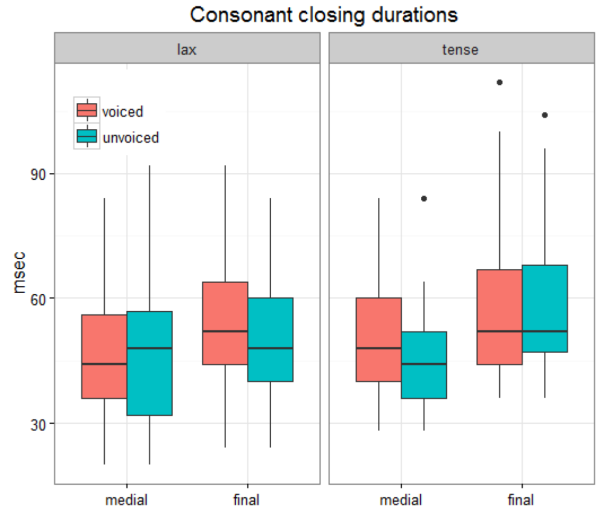

Figure 5: *Articulatory closing duration for consonants following lax vs. tense vowels in phrase-medial vs. phrase-final position. Red (left) boxes represent voiced targets; blue (right) boxes represent unvoiced targets.*

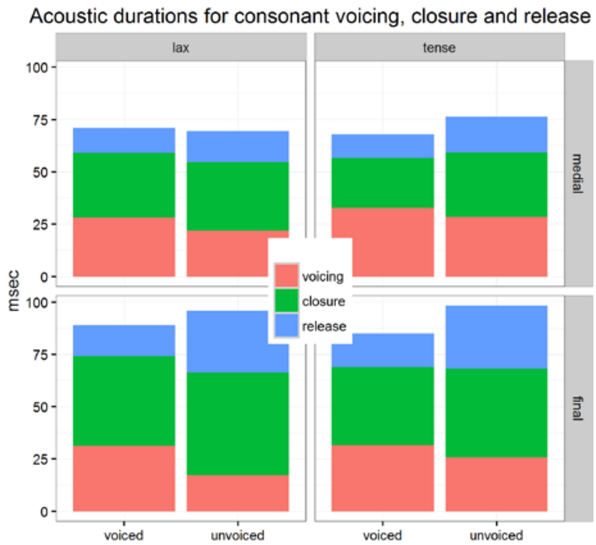

Figure 6: *Acoustic durations for voicing into closure (red), consonant closure duration (green) and consonant release burst including aspiration (blue), split for tenseness and position.*

The logarithmic aspiration duration (cf. the blue bars in Fig. 6) exhibit a longer duration for unvoiced targets ($\beta = -.26$, se = .07, $p < .001$), and an interaction of position and voicing ($\beta = -.26$, se = .1, $p < .05$) as this effect is stronger for phrase-final positions.

4. Discussion and Conclusion

German speakers show similar prosodic behavior concerning final lengthening in acoustic vowel duration when speaking L1 German and L2 English, confirming Hypothesis 1. For both target languages, vowel duration is lengthened in phrase-final position, but lax vowels lengthen less than tense vowels. For the English targets, German learners exhibit longer consonant closing durations (cf. Fig. 2), with a stronger lengthening effect for closing duration following tense vowels in phrase-final position. Unexpectedly, consonant plateau duration for the English targets is significantly shorter than for the German targets in final position. Generally, our results on final lengthening could be explained by either a transfer effect from L1 German to L2 English, by the advanced L2 English proficiency, or because German and English are similar with respect to final lengthening. In order to tease these possible causes apart, comparable data by native speakers of English are needed.

The second part of this study adheres to voicing contrast. The articulatory data for consonant closing and plateau duration of voiced vs. unvoiced targets are inconsistent. Together with the acoustic vowel length, no differences in voicing can be found. Looking at individual speakers, only two of the 8 subjects produce a pronounced difference in vowel duration before voiced vs. voiceless consonants. Thus, vowel length does not differ consistently for voiced vs. unvoiced consonants, despite the fact that pre-consonantal vowel lengthening is a reliable voicing cue in L1 English, cf. [11]. Significant differences in the voicing contrast manifest in the acoustic parameters during the alveolar stop: duration of voicing during stop consonants, consonant closure duration and aspiration. Voiced targets show a greater amount of voicing duration than unvoiced targets. The acoustic variables show more consistent differences for voicing than the articulatory data since voicing into closure and aspiration reflect glottal activity and lingual-glottal coordination.

Especially interesting are the interactions we found: Consonants after lax vowels in phrase-medial position show a reduced voicing distinction. This could be a reflex of the phonotactic asymmetry in German, see e.g., [16] that in word-medial position voiced obstruents are much more restricted after lax vowels than after tense vowels (e.g., words like *Ebbe)*. The result that the voicing distinction is more pronounced in final position is in line with [17] who found evidence for incomplete voicing neutralization in utterance-final positions in German.

In sum, this study presents first results on the prosodic variation and the voicing distinction, produced by German learners of English, and considered measurements of acoustic and articulatory data, different phrasal positions as well tenseness of vowels, factors that have not been taken into account in other studies, e.g., [11]. Future work will compare these results to native English speakers and will test whether and how deviations from the English norm contribute to a perceived foreign accent.

5. References

[1] M. E. Beckman, J. Edwards, and J. Fletcher, “Prosodic structure and tempo in a sonority model of articulatory dynamics,” in *Papers in Laboratory Phonology II*, Papers in Laboratory Phonology, M. E. Beckman and J. Kingston, Eds. Cambridge: Cambridge University Press, 1992, vol. 2, pp. 68–86.

[2] D. Byrd and E. Saltzman, “Intragestural dynamics of multiple prosodic boundaries,” *Journal of Phonetics*, vol. 26, no. 2, pp. 173–199, 1998.

[3] D. Byrd, J. Krivokapić, and S. Lee, “How far, how long: On the temporal scope of prosodic boundary effects,” *The Journal of the Acoustical Society of America*, vol. 120, no. 3, pp. 1589–1599, 2006.

[4] A. E. Turk and S. Shattuck-Hufnagel, “Multiple targets of phrase-final lengthening in American English words,” *Journal of Phonetics*, vol. 35, no. 4, pp. 445–472, 2007.

[5] R. Berkovits, “Durational effects in final lengthening, gapping, and contrastive stress,” *Language and Speech*, vol. 37, no. 3, pp. 237–250, 1994.

[6] D. Byrd, “Articulatory Vowel Lengthening and Coordination at Phrasal Junctures,” *Phonetica*, vol. 57, pp. 3–16, 2000.

[7] P. Hoole and C. Mooshammer, “Articulatory analysis of the German vowel system,” in *Silbenschnitt und Tonakzente*, Linguistische Arbeiten, P. Auer, P. Gilles, and H. Spiekermann, Eds. Tübingen: M. Niemeyer, 2002, vol. 463, pp. 129–152.

[8] C. Mooshammer and S. Fuchs, “Stress distinction in German: simulating kinematic parameters of tongue-tip gestures,” *Journal of Phonetics*, vol. 30, no. 3, pp. 337–355, 2002.

[9] M. Belz, O. Rasskazova, M. Weirich, A. Riemenschneider, J. Krivokapić, and C. Mooshammer, “Artikulatorische und akustische Untersuchungen zur finalen Längung im Deutschen.” [Online]. Available: http://www.online.uni-marburg.de/pundp11/talks/Belz etal.pdf

[10] ——, “Final lengthening in German,” Cornell University Ithaca, NY, 2016. [Online]. Available: http://www.labphon.org/labphon15/long abstracts/LabPhon15 Revised abstract 61.pdf

[11] B. L. Smith, R. Hayes-Harb, M. Bruss, and A. Harker, “Production and perception of voicing and devoicing in similar German and English word pairs by native speakers of German,” *Journal of Phonetics*, vol. 37, no. 3, pp. 257–275, 2009.

[12] P. Boersma, “Praat, a system for doing phonetics by computer,” *Glot International*, vol. 5, no. 9, pp. 341–345, 2001.

[13] R Core Team, “R: A language and environment for statistical computing,” Wien, 2016.

[14] D. Bates, M. Mächler, B. Bolker, and S. Walker, “Fitting Linear Mixed-Effects Models Using lme4,” *Journal of Statistical Software*, vol. 67, no. 1, pp. 1–48, 2015.

[15] A. Kuznetsova, P. B. Brockhoff, and R. H. B. Christensen, “lmerTest: tests in linear mixed effects models,” 2015.

[16] C. Féry, “Final Devoicing and the stratification of the lexicon in German,” in *Proceedings of HILP 4*, 1999.

[17] H. G. Piroth and P. M. Janker, “Speaker-dependent differences in voicing and devoicing of German obstruents,” *Journal of Phonetics*, vol. 32, no. 1, pp. 81–109, 2004.