# Tongue dynamics at word-boundaries in English and English-accented German: the influence of prosodic structure and word-initial glottalisation

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We analyse tongue tip velocity contours at word boundaries by means of Functional Data Analysis (FDA) to uncover the influence of prosodic structure and of word-initial glottalisation on tongue dynamics in contexts in which /r/-sandhi can occur.

In Southern British English word-final /r/ is normally not articulated, e.g. *cider* as /ˈsaɪdə/, but /r/-sandhi can take place if a word-initial vowel follows [6], e.g. *cider apples* can be pronounced as /ˈsaɪdəˈræpəlz/. In the traditional view word-initial glottalisation blocks sandhi, however it is possible that both phenomena could co-occur, as [11] found for English /l/.

The data in the present study consists of ultrasound tongue images of native English and of English-accented German speech. The choice of the L1 English-L2 German language pair is motivated by the frequent word-initial glottalisations in German [10], which are supposed to affect sandhi occurrence. In English, word-initial glottalisations are less frequent and influenced by prosodic structure: they are more likely to occur at phrase boundaries and pitch accented words [7]. The interplay of exernal sandhi and word-initial glottalisation requires to be studied further [11].

The transfer of external sandhi in the interlanguage has been seldom investigated and with conflicting results [12]. Regarding glottalisation, studies on German and on Czech native speakers indicate that they transfer the frequent word-initial glottalisations from their native language to their English productions [4, 3].

We hypothesise that tongue dynamics as well as the occurrence of /r/-sandhi are influenced by prosodic structure, not by word-initial glottalisation. Regarding the transfer of external sandhi to the interlanguage, we propose two alternative hypotheses: a) transfer takes place, b) speakers do not apply sandhi-rules to their L2 and treat each word as a separate unit, as in the *word integrity hypothesis* suggested by [5].

We carried out simultaneous acoustic and tongue ultrasound recordings of English native speakers reading English and German sentences which were answers to questions. The sentences contained a sequence of two words, word 1 and word 2, in which word 1 ended with /r/, /n/ or /i/ and word 2 started with a low vowel. Between the two words there was a phrase boundary or not, and word 2 could be accented or deaccented, thus phrasing and focus were varied according to four possible combinations. The sentences were repeated six times for a total of 144 sentences. The following is an example of the phrase-medial deaccented condition with word-final /r/ in English (target words in bold):

Question: *If Klingons love baked apples, what else do they like?*
Answer: *Besides baked apples,* ***cider apples*** *are very popular.*

Tongue movements were captured by means of a high-speed Sonix RP ultrasound system with 121.5 frames per second. The measured coordinates were 42 equidistant radials (fanlines) centered at the ultrasound probe. For each speaker we identified the fanline along which the tongue tip showed maximum displacement (see Figure 1) [9] and we calculated tongue tip velocity along that fanline with the software AAA [1]. Velocity was calculated from the onset of the last syllable of word 1 until the offset of the first vowel of word 2, e.g. from the closure of the /d/ in *cider* until the offset of the first vowel in *apples*.

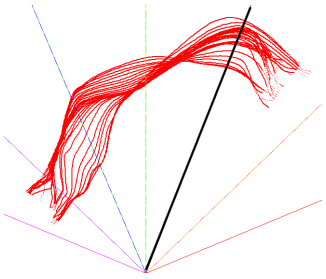

Figure 1: Selected fan line (14) in black for the analysis of tongue tip velocity for speaker en003; tongue contours in red (mid-sagittal view, tongue tip on the right).

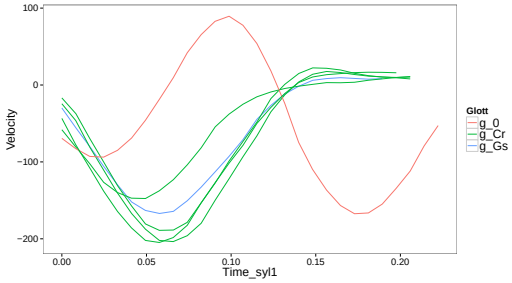


Figure 2: Velocity contours (mm/sec) for speaker en003 in the phrase-medial deaccented condition with final /r/; underlying glottal phenomena: g_0 = no glottalisation, g_Cr = creaky voice, g_Gs = glottal stop.

The tongue tip velocity contours (see example in Figure 2) were analysed by means of Functional Principal Component Analysis (FPCA) [8]. The resulting principal component scores were fitted to Linear Mixed Models [2].

Results will be reported and discussed in light of the models presented above.


[1] *Articulate Assistant Advanced ultrasound module user manual: Revision 2.16*. Edinburgh, UK: Articulate Instruments Ltd, 2014.

[2] Douglas Bates, Martin Mächler, Ben Bolker, and Steve Walker. Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1):1–48, 2015.

[3] M.P. Bissiri. Glottalizations in German-accented English in relationship to phrase boundaries. In *Systemtheorie Signalverarbeitung Sprachtechnologie*, pages 234–240. TUD, Dresden, 2013.

[4] M.P. Bissiri and J. Volín. Prosodic structure as a predictor of glottal stops before word-initial vowels in Czech English. In R. Vích, editor, *20th Czech-German Workshop - Speech Processing*, pages 23–28. Prague, 2010.

[5] Juli Cebrian. Transferability and productivity of L1 rules in Catalan-English interlanguage. *Studies in Second Language Acquisition*, 22:1–26, 2000.

[6] A. Cruttenden and A.C. Gimson. *Gimson's pronunciation of English, revised by Alan Cruttenden*. Edward Arnold, London, fifth edition, 1994.

[7] L. Dilley, S. Shattuck-Hufnagel, and M. Ostendorf. Glottalization of word-initial vowels as a function of prosodic structure. *Journal of Phonetics*, 24:423–444, 1996.

[8] M. Gubian, F. Torreira, and L. Boves. Using functional data analysis for investigating multidimensional dynamic phonetic contrasts. *Journal of Phonetics*, 49:16–40, 2015.

[9] C. Heyde, J. Scobbie, R. Lickley, and E. Drake. How fluent is the fluent speech of people who stutter? a new approach to measuring kinematics with ultrasound. *Clinical linguistics & phonetics*, 30(3-5):292–312, 2016.

[10] K. Kohler. Glottal stops and glottalization in German. Data and theory of connected speech processes. *Phonetica*, 51:38–51, 1994.

[11] J. Scobbie and M. Pouplier. The role of syllable structure in external sandhi: an EPG study of vocalisation and retraction in word-final English /l/. *Journal of Phonetics*, 38:240–259, 2010.

[12] E.C. Zsiga. External sandhi in a second language: The phonetics and phonology of obstruent nasalization in Korean-accented English. *Language*, 87:289–345, 2011.