Where /aR/ the /R/s in Standard Austrian German?

Anke Jackschina[1], *Barbara Schuppler*[2], *Rudolf Muhr*[1],

[1]Forschungsstelle Österreichisches Deutsch, University of Graz, Austria
[2]Signal Processing and Speech Communication Laboratory, Graz University of Technology, Austria
b.schuppler@tugraz.at, anke.jackschina@gmail.com, rudolf.muhr@uni-graz.at

Abstract

The present paper investigates the conditions under which different realizations of /R/ occur in standard Austrian German. The study is based on 509 word tokens containing the phone sequence /a(:)R/ in coda position drawn from a corpus of read speech from male Austrian radio speakers. Acoustic measurements of the vowel /a(:)/ revealed that F1, F2 and F3 are significant predictors for the realization of /R/ as either trill, fricative or as absent. Moreover, /a(:)/ tends to be longer when /R/ is absent than when it is present. Our analysis of the linguistic conditions for the different realizations of /R/ showed that /R/ is least reduced in stressed syllables and in words read in isolation. Furthermore, we observe that the segmental context significantly affects the realization of /R/. Most importantly, we find significant effects of morphology: /R/ tends to be more reduced when it is part of a grammatical morpheme than when it is part of the stem of a word. These findings inform the further development of models of pronunciation variation for human and automatic speech recognition.

Index Terms: Austrian German, /R/ reduction, morphologic effects, prosodic effects

1. Introduction

Whereas for the varieties of German spoken in Germany, pronunciation variation and phonetic detail has been given a lot of attention in the fields of linguistics and automatic speech recognition [1, 2, 3], for Austrian there is a lack in speech resources as well as linguistic and phonetic studies. /R/ is one of the phonemes in German with the greatest variation for its phonetic realization. Not surprisingly, also phonetic studies about /R/ are widespread for the varieties spoken in Germany [4, 5, 6, 7, 8, 9]. For the spoken standard in Austria, however, only little is known about the conditions for the different realizations of /R/ [10, 11, 12, 13]. The current paper presents an auditory and acoustic investigation of the phoneme /R/ in the sequence /a(:)R/ in standard Austrian German and analyzes the linguistic conditions (i.e., prosodic and morphological properties, segmental context) under which the different acoustic realizations of /R/ are likely to occur.

The occurrence of these different varieties is not only conditioned by the social and regional background of the speakers, but also by the segmental context and the syllabic structure of the words. Whereas /R/ is mostly vocalized as /ɒ/ after vowels in coda positions, after /a(:)/ it has been observed to be frequently reduced and deleted, also in carefully pronounced read speech. For the current study, we chose to analyze coda /R/ following /a/ since on the one hand /R/ is highly variable in this context but on the other hand /a/ has been reported to show very little variation in standard Austrian German. Iivonen [4], for instance supposed that there is only one [a], but which has context-dependent differences in the length. In his comparison the acoustic properties of /a/ in read sentences by Viennese and German speakers, he found that, whereas for German speakers F1 and F2 differ significantly for short and long /a/ , for Austrian speakers F1 and F2 are nearly the same.

Previous studies on the realization of /R/ in Austrian German are very limited. Ulbrich, H. [6], for instance, studied the speech from 45 male and female German newsreaders and actors. He found that the fricative [ʁ] is frequently realized after [aː], and that the absence of /R/ after /a(:)/ is only marginally in standard German. For standard Austrian German, Klaaß[13] reports that the most common realization of /R/ after vowel is the vocalization. Also these results are based on auditory phonetic analysis only. In contrast to these studies, we base our analysis on more heterogenous data and we carry out acoustic measurements of /R/ and its preceding vowel /a(:)/.

Another relevant study on Austrian German has been presented in [12]. She compared read speech from radio speakers from Austria, Switzerland and Germany and shows typical phonological attributes of the standard pronunciation of each country. One of her findings is that the duration of stressed syllables is higher than the duration of unstressed syllables (a finding also reported in [14]). The study of Spieckermann [9] shows amongst others that the changes in formants of the nucleus of an accented syllable depend on the place of articulation of the surrounded consonants. Also in the present study, we will investigate the effect of the realization of /R/ on the formants of the preceding vowel and whether these effects are different in stressed and unstressed syllables.

Recently, several studies on Germanic languages have reported effects of the morphological properties of a word on its phonetic realization (e.g., for English [15], for Dutch [16]). For instance, Schuppler et al. [17] found that /t/ tends to be more often deleted when being part of the stem of a word than when being a grammatical morpheme. They argue that a stem is derived from the mental lexicon as a whole and thus more likely to be reduced than grammatical morphemes which are added to a stem. In the current study, we will investigate whether the realization of /R/ differs when it is part of the stem of a word compared to when it is part of a grammatical morpheme.

The aim of the present paper is two-fold: The first aim is to investigate which are the linguistic properties of the words which predict the different realizations of /R/ in the phone sequence /ar/ in Austrian German. The second aim is to study how these different realizations of /R/ affect the acoustic properties of the preceding vowel /a(:)/ (F1 - F3, duration). In the following sections we will first describe the material used and then our auditory and acoustic phonetic analyses. Subsequently, we will present our results and discuss them in the light of previous findings from the literature.

2. Materials and Method

2.1. Speech material

We extracted word tokens containing the sequence /a(:)R/ (with /R/ being in syllabic coda position) from two different sources: First, we extracted 468 tokens from the ADABA corpus ("Aussprachedatenbank", cf. Muhr [5], [6]), which contains studio recordings of read speech produced by male trained speakers of standard Austrian German. Second, we extracted 42 tokens from read speech produced by male Austrian radio narrators. We extracted these tokens from a corpus, which consists of 245 sentences produced in 30 minutes of speech by six male and eight female narrators from three Austrian radio stations (i.e., ORF1, ORF 2 and Antenne Steiermark). In total, we have 509 tokens from 486 word types for our analysis.

2.2. Auditory and acoustic analysis

The first author of this paper listened to all tokens once without inspection of the spectrogram and another two times with the acoustic signal and spectrogram. Each time she annotated the /R/ as either produced with a trill, a fricative, deleted without lengthening of /a/ or deleted including compensational lengthening of /a(:)/. Furthermore, she annotated for each token whether it carried syllabic stress (primary, secondary, none) and sentence accent (yes, no).

Acoustic analyses of all tokens were carried out using the software PRAAT [18]. For each token a TextGrid with three interval tiers was created: one for word, one for the complete sequence /a(:)R/ and /a(:)/ /R/. All boundaries between sounds were set following the guidelines provided in [19]. Subsequently boundaries were moved to the nearest zero crossing. Based on these boundaries we extracted the segment and word durations. In order to measure the formants F1-F3 we selected the vowel including its transitions to the other segments and fixed the boundaries right and left. In the case of preceding voiceless segments, the first positive zero crossing was determined as the start of the vowel. The last full period similar to the preceding ones, or the start of a periodicity was determined as the end of the vowel [14]. For measuring the formants, we applied the method presented in [14], which is also suitable for short vowels, which sometimes do not show any steady state portion . The duration of /a(:)/ here is to see as a absolute value and adequate for our results.

The average formant valued for all tokens in our data are F1 = 694Hz, F2 = 1343Hz and F3 = 2481Hz. These values are similar to what has previously been reported for /a(:)/ in spoken German. Iivonen, M. [11] , for instance, reported a mean F1 of 700 Hz and a mean F2 of 1300 Hz.

2.3. Statistical analysis

In order to estimate the effects of the different predictors for the different realizations of /R/, we fitted logistic regression models with a binomial logit link function and contrast coding. For this purpose, we used the R package for statistical computation [20]. We followed the following procedure: First, we built a control model with the prosodic variables. To this model, we separately added the morphologic variables, the independent variables that capture the details of segmental context. Interactions between the variables were tested both two-way and as a set. Furthermore, significantly correlating factors were orthogonalized (i.e., when two variables correlated, one variable was substituted by the residuals of a linear model in which it was predicted by the other variable). Predictors and interactions that were not statistically significant were removed. The models presented in the following section thus only contain the remaining significant predictors.

3. Results and Discussion

On the basis of the auditory analysis of the complete data set, we observed that in 22.0% of all /ar/ tokens were absent. 58% of the tokens were produced with a trill, 19% were produced with a fricative, 8% were completely deleted and 15% were deleted including lengthening of /a(:)/.

The following analysis was motivated by two main questions (1) Which higher linguistic properties predict the different realizations of /R/ in the phone sequence /a(:)R/ in Austrian German (absent versus presence of /R/; /R/ realized as fricative vs. trill) ? (2) How do these different realizations of /R/ affect the preceding vowel /a(:)/?

3.1. Presence versus absence of /R/

3.1.1. Control Model (CM1) : Effects of prosody

The independent variables of the Control Model (CM, cf. Table 1) were: the prosodic variables *Stress* (52.1% of the tokens carried primary syllabic stress, 29.1% secondary stress and 18.8% without stress) and *Number of Syllables* in the word (ranging between one and eight syllables, with a mean of 2.9). Furthermore, we added the variables *Position in Word*, which can have the values word-initial-syllable (57.2%), word-medial-syllable (22.2%) and word-final-syllable (20.6%). As several studies have shown that function words tend to be more reduced than content words (e.g., [21]), we included the independent variable *Word Class* (function word or content word). Finally, we also added the variable *Isolated*, which indicated whether words were read in isolation or within a sentence. The CM was calculated for the complete data set (N = 509).

The results for the CM are shown in Table 1. We find that the prosodic variable *Stress* is a significant predictor for the absence versus presence of /R/. /R/ is significantly more often deleted in unstressed syllables (46.9%) than in secondary (19.6%) and primary stressed syllables (14.3%). These results are in line with previous results on other Germanic languages. For instance, for English it has been shown that stressed syllables tend to be longer than unstressed syllables [22] and for Dutch it has been shown that they tend to be less prone for speech reduction [17]. Our results also show that /R/ is significantly more often deleted in word-final position (48.6%) than in word-medial (17.7%) and word-initial position (14.1%).

Also the independent variable *Isolated* resulted to be a significant predictor in the CM, with significantly more deletions of /R/ in words that were read within a longer sentence (63.4%) than for words read in isolation (18.4%). This result is as expected, since one can assume that when words are read in isolations, all segments tend to be clearly pronounced and coarticulation and reduction is less pervasive.

3.1.2. Effects of morphology

In order to analyze whether the morphological properties of the word influence the realization of coda /R/, we added the independent variable *Morphology* to the control model (CM1). Morphology distinguishes word tokens where /a(:)R/ is part of a grammatical morpheme (e.g., wunder-bar wonderful) and tokens where /a(:)R/ is part of the stem of a word (e.g., Formular form). *Morphology* resulted to be a significant predic-

Absence vs. presence of /R/				Realization of /R/ as fricative or vibrant			
Control model CM1				**Control model CM2**			
$N = 509$	β	z-value	p-value	$N = 397$	β	z-value	p-value
Intercept	-1.71	0.46	<.0001	Intercept	-0.30	0.53	<1
Stress 'secondary'	-0.21	0.33	<1	Stress 'secondary'	-0.90	0.27	<.0001
Stress 'none'	-1.32	0.33	<.0001	Stress 'none'	-0.92	0.34	<.001
Isolated 'yes'	2.56	0.39	<.0001	Isolated 'yes'	1.91	0.56	<.0001
Position Word 'initial'	1.63	0.31	<.0001				
Position Word 'medial'	1.26	0.34	<.0001				

Table 1: **Control Models:** CM1 for absence vs. presence of /R/ and CM2 the realization of /r/ as fricative or vibrant.

tor ($\beta = 1.58$, $z = 3.69$, $p < .0001$): /aR/ is significantly more often produced as /a(:)/ when occurring in a grammatical morpheme (62.1%) than when being part of the stem of a word (18.9%). Even though *Morphology* and *Position in Word* did not correlate significantly, we tested whether this effect of morphology also was true only for word-final /ar/ sequences. Thus, we built a model on only those tokens, where /ar/ occurred in word-final position (N = 105). Also on this subset *Morphology* resulted to be significant ($\beta = 2.09$, $z = 3.74$, $p < .0001$).

These results are opposite to the findings presented in [17]. They have found that /t/ tends to be more often deleted when being part of the stem of a word than when being a grammatical morpheme. They argue that a stem is derived from the mental lexicon as a whole and thus more likely to be reduced than grammatical morphemes which are added to a stem. This reasoning is only partially true for the current study. Whereas in [17] exclusively inflectional morphemes were analyzed (where speakers need to choose between an inflectional paradigm), most of our grammatical morphemes were suffixes (i.e., *-bar*), which are used to create adjectives (and where no choice needs to be made). In addition, in German adjectives can easily be distinguished from nouns by their position in the sentence. Thus, we suggest that the higher degree of reduction of /R/ in grammatical morphemes in our German data can be explained by the the lower information load of grammatical morphemes compared to the stems of words.

3.1.3. Effects of segmental context

In order to investigate the effect of the preceding context of the sequence /aR/, we fitted a model on those tokens, where /ar/ was not word-initial (N = 436). The independent variables added to the control model were *Morphology, Preceding Manner* (fricative, nasal, plosive and rest), *Preceding Place* with the values front (i.e., bilabial, labiodental) , mid (i.e., alveolar, palatal) and back (velar, uvular), and *Preceding Voiced*, which indicates whether the preceding consonant is voiced. *Preceding Manner* resulted to be the only significant factor: /a(:)R/ is significantly less likely to be realized as /a(:)/ after nasals (11.9%) and fricatives (15.1%) than after plosives (29%; $\beta = -1.44$, $z = -2.45$, $p < .01$) and rest (46.0%; $\beta = -2.54$, $z = -3.36$, $p < .0001$).

For the analysis of the effect of following context, we fitted a model on those tokens, where /a(:)R/ was not word-final (N = 429). The independent variables added to the control model were *Morphology, Following Manner, Following Place* and *Following Voiced*, with the same values as described for the preceding context. Similar as for the preceding context, we observe effects of *Following Manner*. The sequence /a(:)R/ is significantly less probable to be reduced to /a/ before plosives (6.8%, $\beta = 3.32$, $z = 2.96$, $p < .001$) than before nasals (13.3%), fricatives (29.8%) and rest (52.3%). These findings are in line with the counts of /R/s presented by [13], who mentioned that most instances of /R/ were realized before plosives.

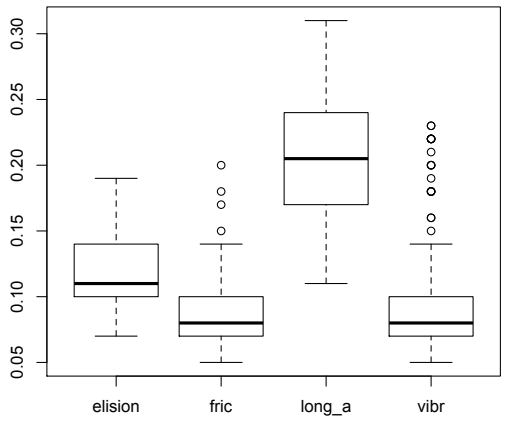

Figure 1: Boxplot for the duration of the vowel /a(:)/ preceding /R/ for the different perceptual categories of /R/: fricative, vibrant (i.e., trill), deleted or with a longer preceding /a(:)/.

3.1.4. Acoustic measures of the preceding vowel /a/ as predictors for /r/ deletion

As described in Section 2.2, we measured the duration and the formants F1-F3 of the vowel /a(:)/ which precede /R/. The aim was to investigate whether /a(:)/ differs acoustically in tokens where /R/ is absent from tokens where it is not absent. For the statistical analysis, we added the measures Duration (in ms), F1, F2 and F3 (in Hz) to a model with all significant predictors presented in the previous section (i.e., Control Model, Morphology, Preceding Context, Following Context). *Duration* showed to be a significant predictor ($\beta = -28.4$, $z = -5.33$, $p < .0001$), with a significant interaction with Stress (Interaction Duration and Stress: $\beta = -38.3$, $z = -2.76$, $p < .001$): the longer /a/ the more likely it is that /r/ is deleted, and this effect is strongest for stressed syllables. Figure 1 shows a boxplot for the durations of /a(:)/ for the different realizations of /R/.

Furthermore, we found that F1 is significantly lower ($\beta = 0.01$, $z = 4.32$, $p < .0001$) when /R/ is absent (mean = 657Hz)

than when it is realized as either fricative or trill (mean = 704 Hz). F2 resulted to be significantly higher ($\beta = 0.01$, $z = 2.45$, $p < .01$) when /R/ is absent (mean= 1350Hz) than when it is present (mean = 1341Hz), and this effect of F2 is stronger for syllables carrying primary accent than for those with secondary accent or no accent at all (Interaction Stress and F2: ($\beta = -0.01$, $z = -2.11$, $p < .001$). Finally, our data shows that F3 is a highly significant predictor ($\beta = -0.01$, $z = - - 4.35$, $p < .0001$): the preceding /a(:)/ tends to have higher F3 (mean = 2608 Hz) in tokens where /R/ is absent than when it is realized as fricative or trill (mean = 2445 Hz).

3.2. Realization of /R/ as either fricative or trill

3.2.1. Control Model (CM2) : Effects of prosody

Also for investigating which are the properties which predict whether the /r/ in the sequence /ar/ was realized as fricative or trill, we first fitted a Control Model (CM2 cf. Table 1) on all word tokens where /r/ was not deleted (N = 397). Overall, 25.2% of the tokens in this data set were produced as fricative (and 74.8% as trill, respectively). We included the same independent variables as described in Section 3.1.1. In contrast to our results on the complete data set, *Position in the Word* appear not to affect the realization of /r/ as either fricative or trill. The independent variables *Isolated* and *Stress*, however, resulted to be significant predictors: /R/ is more likely to be realized as trill in words read in isolation (40.0%) than in words embedded in longer sentences (76.2%) and /R/ is more likely to be realized as trill in stressed syllables (76.2%) than in unstressed syllables (66.7%).

3.2.2. Effects of morphology

As a next step, we added the independent variable Morphology to CM2. Also in the subset of not-deleted /r/ in the sequence /ar/, Morphology resulted to be a significant predictor ($\beta = 2.08$, $z = 3.18$, $p < .001$): /r/ is more likely to be realized as trill when /r/ is part of the stem of a word (76.5%) than when it is a grammatical morpheme (28.6%). These results to into the same directions as our results concerning the morphological effects on the absence vs. presence of /R/: in grammatical morphemes reduced realizations of /R/ are more likely than when /R/ is part of the stem of a words.

3.2.3. Effects of Segmental context

In order to investigate the effect of the preceding context, we fitted a model on those tokens, where /ar/ was not word-initial (N = 324). *Preceding Place* resulted to be the only significant factor: /r/ is significantly more likely to be realized as fricative when /ar/ is preceded by a consonant in front (34.3%, $\beta = -1.14$, $z = -2.37$, $p < .01$), than when preceded by a consonant in medial (20.0%) or in back (15.5%) position. For the analysis of the effect of following context, we fitted a model on those tokens, where /ar/ was not word-final (N = 367). Our data shows significant effects for *Following Voice* ($\beta = 1.93$, $z = 4.96$, $p < .0001$): /r/ is more likely to be produced as a trill when followed by a voiced sound (91.0%) than when followed by a voiceless sound (65.3%).

3.2.4. Acoustic measures of the preceding vowel /a/

In order to investigate whether the acoustic properties of the preceding vowel /a(:)/ is affected by the realization of /R/ as either trill or fricative, we added the variables *Duration, F1, F2* and *F3* to the control model CM2. We did not find significant effects of *Duration* and *F1*. Thus, our data suggests that the duration and the F1 of the vowel /a/ is not affected by whether /R/ is realized as fricative or trill. F2 is significantly lower for /a/ preceding a fricative realization of /R/ (mean = 1329 Hz) than preceding a trill (mean = 1345 Hz). Finally also F3 appeared to be significantly affected by the manner of articulation of /R/: F3 is significantly higher before [R] (F3mean = 2478Hz) than before [r] (mean = 2434Hz).

Our results concerning the influence of the realization of /R/ on the preceding vowel are in line with previous findings. First, also [9] showed that the formant values of the nuclei of accented syllables depend on the place of articulation of the surrounding consonants. Second, [23] mentioned that the effect of /R/ on preceding vowels is either retraction or centralization and that palatal, dental and alveolar consonants have a high influence on F1 and F2. No previous study reports effects of the realization of /R/ on F3 of the preceding vowel.

4. Concluding Remarks

The aim of the present paper was two-fold: The first aim was to investigate which are the linguistic properties of the words which predict the different realizations of /R/ in the phone sequence /a(:)R/ in Austrian German. Based on 509 word tokens read by trained male Austrian radio speakers, we found that /R/ is least reduced in stressed syllables and in words read in isolation. Furthermore, the segmental context resulted to affect the realization of /R/. /R/ is significantly less likely to be absent when /a(:)R/ is preceded by nasals and fricatives than after plosives. Furthermore, /R/ is most likely to be produced as a trill when followed by a vowel or by a voiced consonant. Most importantly, we found significant effects of morphology: /R/ tends to be more reduced when it is part of a grammatical morpheme than when it is part of the stem of a word.

The second aim of this study was to investigate how the different realizations of /R/ affect the acoustic properties of the preceding vowel /a(:)/. Our acoustic measurements of the vowel /a(:)/ revealed that F1, F2 and F3 are significantly affected by the realization of /R/ as either trill or fricative or when it is acoustically absent. Moreover, /a(:)/ tends to be longer when /R/ is absent than when it is present. These results indicate, that /R/ is not completely deleted: the duration of the preceding vowel /a(:)/ compensates for the absent /R/, and thus the prosodic, rhythmic properties of the word (or utterance) maintain the same.

In sum, we have shown that several factors affect the different realizations of /R/ in standard Austrian German. Our findings will inform the further development of models of pronunciation variation for human and automatic speech recognition. This study, however, is only a first step. We need more studies of the kind presented here (on different consonants and vowels, on different speech styles) in order to increase our understanding of the conditions which affect pronunciation variation in Austrian German.

5. Acknowledgements

The work by Barbara Schuppler was supported by a Hertha-Firnberg grant from the FWF (Austrian Science Fund).

6. References

[1] K. J. Kohler, "Articulatory dynamics of vowels and consonants in speech communication," *Journal of the International Phonetic Association*, vol. 31, pp. 1–16, 2001.

[2] M.-B. Wesenick, "Automatic generation of German pronunciation variants," in *Proceedings of the ICSLP*, 1996, pp. 125–128.

[3] M. Adda-Decker and L. Lamel, "Modeling reduced pronunciations in German," *Phonus 5, Institute of Phonetics, University of the Saarland*, pp. 129–143, 2000.

[4] N. Yoshiyuki, "Akustisch-phonetische Studie über die deutschen Vokale," in *Beiträge zur Phonetik des Deutschen, Forum Phoneticum 14*, H. W. Wodarz, Ed. Buske, 1979, pp. 1–44.

[5] H. J. Hakkarainen, *Phonetik des Deutschen*. München: W. Fink, 1995.

[6] H. Ulbrich, "Instrumentalphonetisch-auditive R-Untersuchungen im Deutschen," *Schriften zur Phonetik, Sprachwissenschaft und Kommunikationsforschung*, vol. 13, 1972.

[7] K. J. Kohler, *Einführung in die Phonetic des Deutschen*. Berlin: Erich Schmidt Verlag, 1977.

[8] W. Krämer, "Iakustisch-phonetische Untersuchungen zum vokalischen /r/- allophon des Deutschen," *Forum Phoneticum*, vol. 20, 1979.

[9] H. Spieckermann, *Silbenschnitt in deutschen Dialekten*. Tübingen: Niemeyer, 2000.

[10] A. Iivonen, "Monophghonge de gehobenen Wienerdeutsch," *Folia linguistica (Acta Societatis Linguisticae Europaeae)*, vol. 21, pp. 293–336, 1987.

[11] ——, "Unterschiede des Vokalismus und der Intonation in der ostmitteldeutschen und wienerdeutschen Sprache," *Hallesche Schriften zur Sprechwissenschaft und Phonetik*, vol. 1, pp. 225–240, 1996.

[12] N. Yoshiyuki, "Phonetische Untersuchungen zur Prosodie der Standardvarietäten des Deutschen in der Bundesrepublik Deutschland, in der Schweiz und in Österreich," *Hallesche Schriften zur Sprechwissenschaft und Phonetik*, vol. 16, 2005.

[13] D. Klaaß, "Untersuchungen zu ausgewählten Aspekten des Konsonantismus bei österreichischen Nachrichtensprechern," *Duisburger Papers on Research in Language and Culture*, vol. 74, pp. 7–277, 2008.

[14] S. Moosmüller, *Vowels in Standard Austrian German. An Acoustic-Phonetic and Phonological Analysis.* Habilitation, University of Vienna, 2007.

[15] J. Hay, *Causes and Consequences of Word Structure*. New York and London: Routledge, 2003.

[16] V. Kuperman, M. Pluymaekers, M. Ernestus, and R. H. Baayen, "Morphological predictability and acoustic duration of interfixes in Dutch compounds," *J. Acoust. Soc. Am.*, vol. 121, pp. 2261–2271, 2007.

[17] B. Schuppler, W. van Dommelen, J. Koreman, and M. Ernestus, "How linguistic and probabilistic properties of a word affect the realization of its final /t/: Studies at the phonemic and sub-phonemic level," *Journal of Phonetics*, vol. 40, pp. 595–607, 2012.

[18] P. Boersma, "Praat, a system for doing phonetics by computer," *Glot International*, vol. 5, no. 9/10, pp. 314–345, 2001. [Online]. Available: http://www.praat.org, last viewed 18-08-2010

[19] P. Mahač and R. Skarnitzl, *Principles of phonetic segmentation*. Prague: Epocha Publishing House, 2009.

[20] P. Dalgaard, *Introductory Statistics with R*. New York: Springer, 2002.

[21] K. Johnson, "Massive reduction in conversational American English," in *Spontaneous Speech: Data and Analysis. The National International Institute for Japanese Language*, K. Yoneyama and K.Maekawa, Eds., Tokyo, Japan, 2004, pp. 29–54.

[22] P. Ladefoged, *AUC course in phonetics, 2nd edition*. New York: Hartcourt, Brace, Javanovich, 1982.

[23] K. Lodge, "A declarative treatment of the phonetics and phonology of German rhymal /r/," *Lingua*, vol. 113, pp. 931–951, 2003.