VOWEL SPACE, SPEECH RATE AND LANGUAGE SPACE

Beat Siebenhaar and Matthias Hahn

Universität Leipzig, Germany
siebenhaar@uni-leipzig.de, matthias.hahn@uni-leipzig.de

ABSTRACT

Acceleration of speech rate is often said to be correlated with a reduction of the vowel space. However, a monocausal explanation of the vowel space reduction by speech rate is surely too simplistic. With our regionally balanced database of a German text read in two reading tempi we present geolinguistic maps of

- the different sizes of the vowel space and
- different changes of the sizes of the vowel space when comparing normal and accelerated speech rates.

These maps for the normal reading tempo show regional patterns of vowel space sizes for the long and short vowel system. Accelerating speech rate affects the vowel space size in regionally specific patterns. In addition, increasing reading tempo shows a surprising general effect: initially large vocal spaces are reduced while initially small vocal spaces are enlarged. Interestingly, vowel space size and change due to accelerating reading tempo does only limitedly reflect traditional dialect regions.

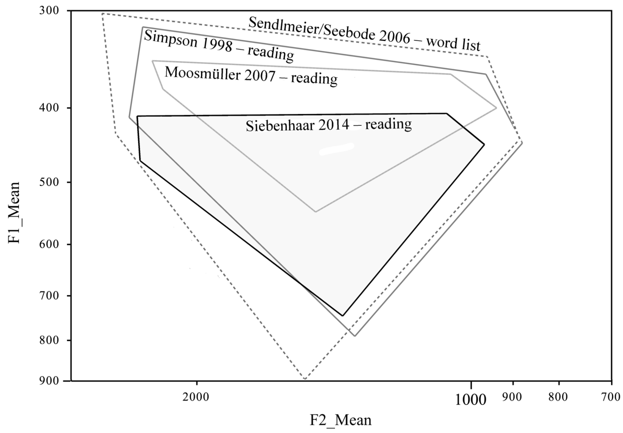
Keywords: German, speech rate, tempo, vowel space, geophonetics

1. INTRODUCTION

Variationist geolinguistic and sociophonetic research focuses on specific sounds or the relation of sounds within a linguistic system. Realisations of specific sounds are correlated to areal, social or interactional factors. The vowel space is architecturally conceptualized in terms of relative questions like: Is /eː/ more fronted than /iː/? Where is the position of an /aː/? Usually, the size of the vowel space itself is not under investigation. However, comparison of different studies makes it obvious that the vowel space area is quite variable. Fig. 1 shows different representations of the vowel space for the long monophthongs of Standard German. These studies – except for [13] with data from a word list – represent data from reading tasks and have been analysed differently, so that the results are only comparable to a limited extent.

Recordings of [13] were made in Berlin; however, the authors claim that their students had no dialectal influence. [15] analyses the Kiel Corpus [5] with recordings from the northwestern part of Germany. [11] examines data from Vienna, representing an Austrian standard, and [14] looks at data from Leipzig in East Central Germany.

Figure 1: Comparison of the vowel space of long vowels in standard German intended recordings.



This comparison makes it evident that there is variation in the geometry of the vowel space as well as in the size of the vowel space. It also suggests that there is regional variation in Standard-intended German speech – that is, Standard German as performed regionally [4, 7, 8]. Moreover, the analyses [5, 11, 12, 14, 15] document stylistic differences and [18] shows that speech rate affects articulation accuracy in many ways. In addition to segment elision and an increase in coarticulation phenomena, vowel undershoot is a typical feature attributed to higher speech rate. The hypothesis in [9] postulates that a vowel target may not be reached by the articulators under the temporal constraints of an accelerated speech rate, resulting in formant undershoot and a reduction in the vowel space size; however, this theory is by no means universally accepted and findings are inconsistent [12].

With a geographically balanced dataset of German read speech in two speech rates [1, 2, 3] we will focus on the following questions:

- Is there regional variation in vowel space size?
- Is there regional variation in how long and short vowels pattern in terms of vowel space size?
- How does acceleration of speech rate affect these patterns?

2. DATA AND METHODS

2.1. Data

The data are part of the "Deutsch heute" corpus from the Institute for German Language (IDS) [1, 7]. For this study the Aesop fable *The North Wind and the Sun* was used as reading material. This was recorded twice per speaker, once in a "normal" reading tempo, and then in a "fast" reading tempo. The subjects were two male and two female high school students per place. They were aged 17–20, local to the area under investigation, and not professional speakers. The recording took place during lesson time in school in a quiet room. The study area covers the whole contiguous German-speaking area of Germany, Austria, Switzerland, Liechtenstein, East Belgium and South Tyrol, from which 161 evenly distributed locations were selected. Altogether, there are 644 recordings in two reading tempi.

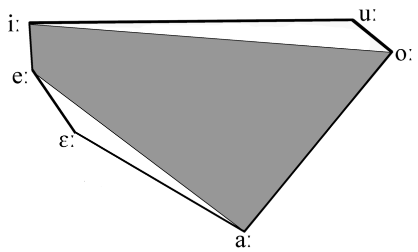
2.2. Preprocessing

For forced alignment we used the Munich Automatic Segmentation tool (MAUS) [6]. Then the first two formants were measured in the central 60% of the monophthongs. A script calculated formant values at 30 positions, then the median of these formant values was taken for each of the 260,000 individual vowels. In order to equalise gender and individual differences, the data were z-normalised [10], that means that the data were transformed in a way that the centre of all vowels got a 0 and the distribution reached a standard deviation of 1. These z-normalised data were the basis for the measurement of the vowel space, represented in z-normalised squared units.

2.3. Measuring the vowel space

The vowel space of the German standard comprises six vowels. However, the *North Wind and the Sun* features only one occurrence of /ɛ:/ and of /u:/ for each recording, so the data density for these two vowels is quite weak. Therefore, we only measure the vowel space for long vowels in the area between /i:/, /e:/, /a:/, and /o:/, marked in Fig. 2 in grey.

Figure 2: Vowel space of the Standard German long vowel system (solid line) and the area used for this paper (shaded area).



The exclusion of /ɛ:/ is not of great concern for this analysis, since there is a tendency for /ɛ:/ and /e:/ to merge as /e:/ in the north of the German-speaking area and in Austria [7]. If /ɛ:/ were taken into account, the vowel spaces would no longer be directly comparable. Omitting /u:/ is more problematic due to its position in the high back corner of the vowel space. However, the available data are not sufficient for the analysis of /u:/.

For the vowel space of the short vowels, we use the corresponding area between /ɪ/, /ɛ/, /a/, and /ɔ/.

To calculate each vowel space, the first two formants of every individual monophthong were measured. Thirty measurements were taken within the central 60% of each vowel, and the median of these was calculated. The data were then Lobanov- or z-normalised [16] – transformed so that the centre of all vowels received a value of 0 and the distribution had a standard deviation of 1. This allows a comparison of speakers with various vocal physiologies [17]. These normalised formant measurements formed the basis for the calculation of vocal space size. The vowel space area for every speaker was measured for long and short vowels separately, each in the normal and fast reading tempi.

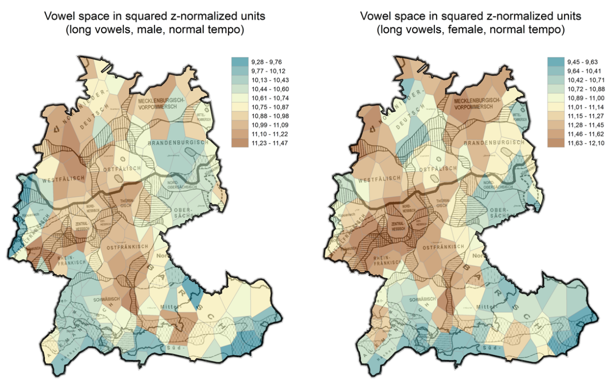
The vowel space values were mapped with ArcGIS using a local smoothing to level out outliers. This means that the value mapped for every polygon represents the median value of this polygon and all its neighbouring values. Thus each area point is represented by 20 to 32 speakers, and because of the robustness against outliers the median is used.

3. RESULTS

3.1. Vowel spaces of males and females

Sociolinguistic research often finds differences between male and female speakers. Therefore, we first compare them to test whether we can treat the datasets of males and females as one larger and therefore generally more reliable dataset, or whether they are distinct. Over the whole dataset, we find correlations of male and female data of r=0.45 for the long vowel system and r=0.48 for the short vowel system, so the chance remains that the datasets of males and females can be treated as one. Fig. 3 maps the vowel spaces of long vowels in normal reading tempo. The brown areas mark larger vowel spaces, the blue areas mark smaller vowel spaces.

Figure 3: Comparison of the vowel space of long vowels in normal reading tempo of male (left) and female (right) speakers. Larger vowel spaces in brown, smaller vowel spaces in blue.

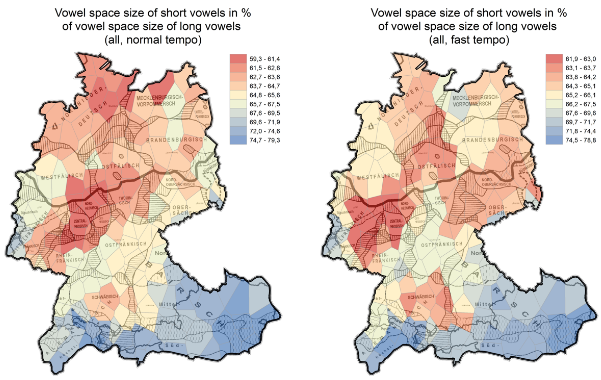


The comparison for the long vowels in normal reading tempo shows very similar regional distributions across genders, with only a few larger differences in the central western part and around Berlin. The correspondences between male and female speakers for the fast reading tempo and for the short vowel system are comparable, but each shows different areal distributions. Finally, it can be said that the regional distributions of vowel space size for men and women are quite similar, though only two men and two women were recorded per place. Therefore, in the following analyses we treat data from males and females in a common dataset.

3.2. Ratio of vowel space sizes of the short vowel to long vowel systems at different reading tempi

Before presenting the vowel spaces for the long and short vowel systems, we will have a look at the relationship between the two systems. Fig. 4 shows the size of the vowel space of the short vowel system as a proportion of the size of the vowel space of the long vowel system. Red areas mark big differences in the size of the vowel spaces of the long and the short vowel system, while blue areas mark smaller differences in the size of the two vowel systems. The two maps in Fig. 4, representing the two reading tempi, are very consistent. This means that changes in reading tempo affect long and short vowels in a similar matter.

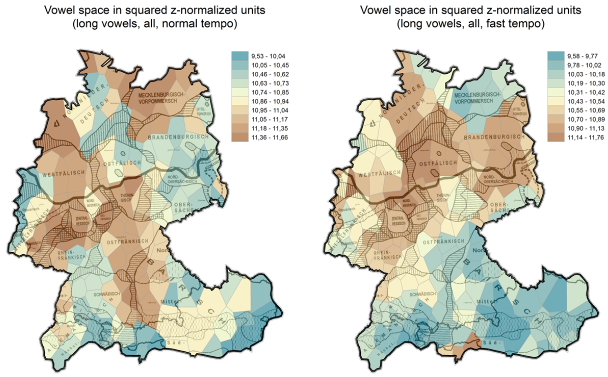
Figure 4: Ratio of the vowel space sizes of the short vowel system to the long vowel system at normal (left) and fast (right) reading tempi. Small differences in red, large differences in blue.



3.3. Comparing normal and fast reading tempi

When we compare the vowel space sizes for long vowels in normal (left) and fast (right) reading tempo (Fig. 5), we find quite different maps. This means that change in tempo does not affect the vowel space size of all regions in the same manner.

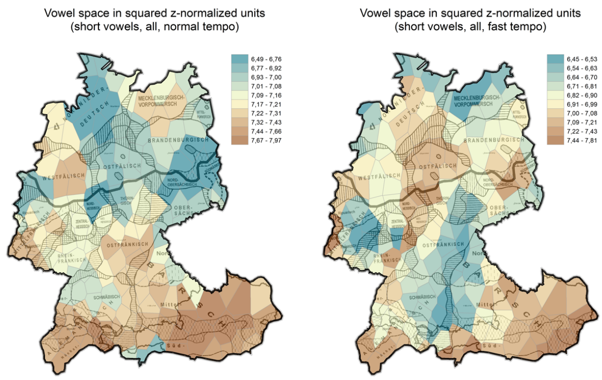
Figure 5: Vowel space size of the long vowel system at normal (left) and fast (right) reading tempi. Large vowel spaces in brown, small vowel spaces in blue.



While the eastern part of Austria and the Alemannic south have quite small vowel space areas in both tempi, there are striking changes in the transition zone from Bavarian to Alemannic and in the north-eastern area of Mecklenburg-Vorpommern.

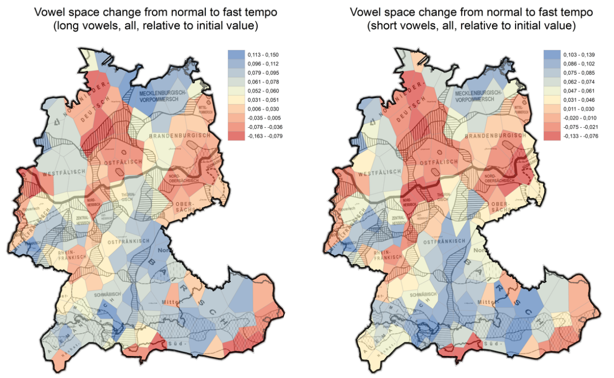
The results for the short vowel system (Fig. 6) seem to be as disparate as for the long vowel system. Here, the south is a bit more consistent than for the long vowel system. For both normal and fast reading tempi, the transition zone from Bavarian to Alemannic and Franconian is separated from the neighbouring areas. Moreover, in the north lower German area and in the Ostfalen area, we find contrary distributions for the two reading tempi.

Figure 6: Vowel space size of the short vowel system at normal (left) and fast (right) reading tempi. Large vowel spaces in brown, small spaces in blue.



Figs. 5 and 6 show that increasing reading tempo does not universally result in the expected reduction of the vowel space. In some regions there is even an enlargement of the vowel space. However, comparison of the corresponding maps in Figs. 5 and 6 is rather confusing. Therefore, the ratio of the vowel space size of the fast reading tempo to the normal reading tempo was calculated for the long vowel system and the short vowel system. The result is given in Fig. 7, showing in red the reduction of the vowel space with an increase in reading tempo, and in blue the expansion of the vowel space with an increase in reading tempo.

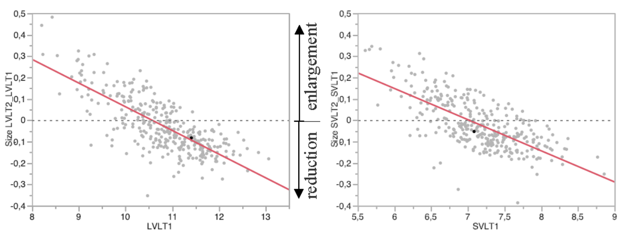
Figure 7: Vowel space size change with increasing tempo of the long vowel system (left) and the short vowel system (right). Reduction of vowel spaces in red, enlargements of vowel spaces in blue.



When we compare the changes for the long and short vowel systems, the two pictures show a very high correspondence. The areas where the vowel space is enlarged when people speak faster are almost identical. So, concerning the adjustments of vowel space size, strategies for speaking faster are identical for the long and the short systems.

When comparing the percent change of the vowel space size with total vowel space size at normal reading tempo (the left-side maps in Figs. 6 and 7), we get a quite surprising result. Fig. 8 shows a negative correlation of vowel space size in normal tempo with amount of reduction when reading faster. The regression models are highly significant (Long vowel system (left): $F(1,160) = 271.9169$; $p < 0.001$; Short vowel system (right): $F(1,160) = 201.2398$; $p < 0.001$). So, we find that regions with a relatively large vowel space in normal reading tempo show reduction of the vowel space when reading faster. In regions where people use a relatively small vowel space in normal reading tempo, they enlarge it when reading faster.

Figure 8: Linear regressions, change of vowel space size (%) in fast reading tempo by vowel space size in normal reading tempo by place. Long vowel system (left) and short vowel system (right).



As the vowel space size shows regional patterning, we also find a related geolinguistic distribution of the different strategies when speeding up the speaking tempo (Fig. 7). The maps reflect how the strategies of vowel space size change by increasing reading tempo. The distribution of the data in the Standard-intended reading task does not fit the traditional dialect areas, but it shows a new regional distribution.

4. DISCUSSION AND CONCLUSION

Our results indicate that there are regional patterns of vowel space size in Standard-intended German. Because the patterns are consistent across both male and female voices, the variation seems to not be idiolectal but rather has a strong areal imprint. Accelerating reading tempo does not only affect the temporal domain but also vowel space size. Our analyses likewise show regionally specific reduction patterns for the vowel space.

The relationship between the vowel space sizes of long and short vowels remain fairly stable between reading tempi. Increasing the reading tempo has two different effects: large vowel space sizes are reduced, small vowel space sizes are enlarged.

The geographical distributions of vowel space size in read speech and change due to reading tempo only slightly reflect traditional dialect regions. Overall, the geographical distribution is surprising as the vowel space is based on the qualities of the vowels. However, the traditional maps show relatively large, mostly phonologically motivated differences, whereas there is a phonetic analysis here. While we do not have the corresponding geolinguistic data on the vowel space of the dialects to make a direct comparison, we have to refer to other dialect classifications based on the segmental phonetic level and on morphological structures. Yet there are hardly any similarities to these dialect classifications. The geographical distribution of vowel space size may be interpreted as having little correspondence to segmental phonetic and morphological structures because the linguistic system is independent of its phonetic realisation. This difference would then have nothing to do with the opposition of dialect and standard. One could also argue that this distribution has more to do with the regional distribution of speech rate or segment reduction than with dialect areas [2, 3]. But even these relationships cannot be established unambiguously. Thus, the design and change of the vocal space seems to be a relatively independent parameter, probably due to the fact that it is hardly perceived consciously.

Despite the apparent independence from traditional dialect classifications, reasonably stable geographical patterns emerge with regard to the design of the vocal space. These show that theories of vocal space [9, 12, 17, 18] must not only take into account general aspects of influence such as speech rate, style, and coarticulation, but that social and geographical components must also be taken into account. This means that the influence of speech rate on the shaping of the vowel space is not a universal phenomenon, but can vary even within one language.

5. REFERENCES

[1] Brinckmann, C., et al. 2008. German Today: An areally extensive corpus of spoken Standard German. *Proc. LREC Marrakech*. Paris: ELRA., 3185–3191.

[2] Hahn, M., & Siebenhaar, B. 2016. Sprechtempo und Reduktion im Deutschen (SpuRD). In: Jokisch, O. (ed), *Elektronische Sprachsignalverarbeitung 2016.* Dresden: TUDpress, 198–205.

[3] Hahn, M., & Siebenhaar, B. 2019. Spatial Variation of Articulation Rate and Phonetic Reduction in Standard-Intended German. In Calhoun, S., Escudero, P., Tabain, M., & Warren, P. (eds.), Proceedings of the 19th International Congress of Phonetic Sciences. Melbourne, Australia.

[4] Iivonen, A. 1994. Zur gehobenen regionalen phonetischen Realisierung des Deutschen. In Viereck, W. (ed), *Verhandlungen des Internationalen Dialektologenkongresses Bamberg 29. 7. – 4. 8. 1990* vol 3. Stuttgart, 311–330.

[5] IPDS. 1994–1997. *The Kiel Corpus of Read Speech (vol. 1–4)*. Kiel: Institut für Phonetik und digitale Sprachverarbeitung.

[6] Kisler, T., Reichel, U. D., & Schiel F. 2017. Multilingual processing of speech via web services. *Computer Speech & Language* 45, 326–347.

[7] Kleiner, S. 2011ff. *Atlas zur Aussprache des deutschen Gebrauchsstandards (AADG)*. http://prowiki.ids-mannheim.de/bin/view/AADG/.

[8] König, W. 1989. *Atlas zur Aussprache des Schriftdeutschen in der Bundesrepublik Deutschland*. Ismaning: Hueber.

[9] Lindblom, B. 1963. Spectrographic study of vowel reduction. *J. Acoustical Soc. of America* 35, 1773–1781.

[10] Lobanov, B. M. 1971. Classification of Russian Vowels Spoken by Different Speakes *J. Acoustical Soc. of America* 49: 606–608.

[11] Moosmüller, S. 2007. *Vowels in Standard Austrian German. An Acoustic-Phonetic and Phonological Analysis*. Wien. http://www.kfs.oeaw.ac.at/publications/ habil_2007may28_tableofcontents_zus_final.pdf

[12] Schulz, E., Oh, M. O., Andreeva, B., & Möbius, B. 2016. Impact of prosodic structure and information density on vowel space size. *Proceedings of Speech Prosody 2016*. Boston: ISCA, 350–354.

[13] Sendlmeier, W. F. & Seebode, J. 2006. *Formantkarten des deutschen Vokalsystems.* https://www.kw.tu-berlin. de/fileadmin/a01311100/ Formantkarten_des_deutschen_Vokalsystems_01.pdf

[14] Siebenhaar, B. 2014. Instrumentalphonetische Analysen zur Ausgestaltung des Sprechlagenspektrums in Leipzig. *Zeitschrift für Dialektologie und Linguistik* 81, 151–190.

[15] Simpson, A. P. 1998. *Phonetische Datenbanken des Deutschen in der empirischen Sprachforschung und der phonologischen Theoriebildung*. Kiel: AIPUK.

[16] Thomas, E. R. & Kendall, T. 2007–2015. NORM: The vowel normalization and plotting suite. [Online Resource: http://lingtools.uoregon.edu/norm/norm1.php]

[17] van der Harst, S. 2011. *The Vowel Space Paradox. A Sociophonetic Study on Dutch*. Utrecht: LOT.

[18] Weiss, B. 2008. *Sprechtempoabhängige Aussprachevariationen*. Berlin. http://edoc.hu-berlin.de/dissertationen/weiss-benjamin-2008-05-28/PDF/weiss.pdf