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An acoustic examination of laterals in Lower Sorbian

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Abstract

This study is an acoustic examination of laterals in Lower Sorbian, an endangered language spoken in eastern Germany. Gestural timing effects of the English lateral, /l/, have been well studied, and overall the data suggests different timing patterns for the tongue tip and tongue body gestures in syllable initial (‘clear l’) and syllable final positions (‘dark l’). The coordination between the tongue tip and body in dark laterals has been used to suggest that misperception has led to the cross-linguistically common change from dark /l/ to /w/. Acoustic data for two dialects of Lower Sorbian (one with the dark lateral and one which underwent the sound change to /w/; both have a clear lateral, /l/) was collected and analysed using an Smoothing Spline ANOVA to examine temporal characteristics of these sounds.The findings suggest that there is a difference in the gestural timing between the clear and dark lateral in word initial and final positions. The dark lateral has earlier achievement F2-F1 target, suggesting an earlier achievement of the tongue dorsum retraction; F2-F1 remains low throughout the following vowel, suggesting a backing effect. The clear lateral has intensifying F2-F1 suggesting tongue dorsum retraction over the duration, until the onset of the following vowel. The data also suggests that lenition of the tongue tip in the word final position could likely have been a trigger for the sound change. In word final position, there is also a much higher F3, suggesting weaker lip rounding, resulting in a similar F3 frequency and trajectory for the dark lateral and /w/. This also suggests a similar vocal tract shape between the dark lateral and /w/. Both that dark lateral and /w/ also show a lowering effect on the F2 of the vowel following them.

Keywords: Lower Sorbian, laterals, acoustics

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1 Introduction

Laterals are produced with a midsagittal occlusion and a constriction formation on either or both \sides of the tongue. This allows airflow through the sides of the tongue and also creates anti-resonance from the central portion of the closure acting like a side channel. However, some laterals do also have mid-central airflow due to a small channel, but there is still more lateral airflow than central airflow in these cases [1]. Maddieson's [2] survey of languages indicated that most languages that employ laterals produced in the alveolar/dental region and are voiced. However, laterals do have a large variety of realizations, including different places (ex. retroflex, palatal, and velar) and different manners (ex. approximant and fricative).

Two common laterals among the world's languages are [l], the clear alveolar lateral, and [ɫ], the velarized or dark lateral. These two laterals are present in a number of dialects of Lower Sorbian, although no phonetic work has been carried out examining their acoustic or articulatory characteristics. However, these laterals have been studied extensively in other languages. Narayanan et al.'s [3] study of English clear and dark lateral variants revealed specific differences in articulation across speakers and between each lateral. [l] can be realized as either an apical or laminal closure in the alveolar region. The tongue body position is also highly variable across speakers: the tongue body was lower and more retracted for some speakers, while others had a much more raised tongue body. In all cases, a lateral constriction was formed by drawing the tongue in towards the mid-sagittal plane. The dark lateral has very little contact with the dental/alveolar region and has a high degree of retraction into the uvular/upper-pharyngeal region creating a secondary constriction. However, the degree of tongue dorsum retraction in the uvular/upper-pharyngeal region also varied across speakers. The variation in uvular/upper-pharyngeal region variations mirrors findings by Recasens et al. [4] who found dialect-specific variation that formed a continuum of degrees of darkness and clearness.

Recasens & Espinosa [5] point out that based on other works in Italian [6], Albanian, Breton, Russian [7, 1] and varieties of English [8, 9] that the place of articulation seems to be strongly connected to the degree of clearness or darkness of the lateral: clear variants are alveolar in place, while dark variants are strongly dental. Recasens & Espinosa [5] also note this difference in place is not restricted to just laterals, but it occurs in other coronal consonants (ex. pharyngealized vs. non-pharyngealized consonants in Arabic, [10]).

While syllable position effects are well documented (ex. clear lateral in onset and dark lateral in coda positions for English), Recasens & Espinosa [5] found that this generalization does not hold cross-linguistically. For example, Majorcan /l/ shows no substantial articulatory or acoustic differences in the onset or coda position. Valencian clear /l/, on the other hand was found to be darker word-finally, contrast to expectations that it would behave more similarly to Italian, French, and Spanish clear /l/. Valencian /l/ is less advanced in word-initial position and has a lower F1 and higher F2 as a result of more dorsopalatal contact. These findings suggest not only that there can be multiple positional allophones but that there is not a simple ‘clear/dark’ contrast as described in languages such as English.

The temporal organization for clear and dark varieties of /l/ also differ with respect to their articulatory trajectories. Sproat & Fujimura [11] found that the tongue dorsum gesture precedes the tongue tip gesture for the dark lateral. The apical closure in utterance-final position may even follow the resumption of voicing in American English. However, in Italian [6] the tongue dorsum and tongue tip activity occur synchronously. The articulatory is also longer in duration for the dark lateral than it is for the clear lateral. The acoustic closure, however, exhibits the opposite relationship. The degree to which the timing of these gestures differs is also as gradient as the production of these segments. That is to say, more intermediate degrees of darkness have more intermediate temporal organization.

Gick et al. [12] also examined the gestural timing of laterals (and rhotics) in a cross-linguistics study that included six languages (Western Canadian English, Quebec French, Serbo-Croatian, Korean, Beijing Mandarin and Squamish Salish). The largest finding in the study was that there was no single cross-linguistic timing generalization, contrary to Krakow’s [13] position that there are strong cross-linguistic timing generalizations for liquid production. In the onset position, tongue tip and dorsum gestures where simultaneously coordinated in three of the languages (SC, SS) and other languages showed no tongue dorsum gesture at all (QF, BM, K). One language (WCE) showed a timing lag where the tongue dorsum gesture preceded the tongue tip gesture in the onset position. This suggests that a perceptual recoverability effect plays a large role in the timing of lateral gestures.

Post-vocalic position also shows a tendency for a temporal lag between the tongue tip and tongue dorsum gesture such that the tongue dorsum gesture precedes the tongue tip gesture. However, this generalization did not hold for Korean as there was no temporal lag at all between the two gestures. This suggests that while there may be a tendency for the dorsal gesture to precede the tongue tip gesture in word final position, it is not a universal constraint. Gick et al. [12] also found that there is a universal cross-linguistic tendency to time both of the gestures simultaneously in the intervocalic position. Browman & Goldstein [9] suggest this may be a result of both gestures coordinating with both flanking syllables, forcing a simultaneous relationship regardless of the relationship between the tongue tip and tongue dorsum gesture.

The purpose of this study is to use acoustic measure to determine what timing differences between dark and clear laterals can be observed in the onset and offset positions of Lower Sorbian. Lower Sorbian has also had a shift from dark lateral to a bilabial glide, /w/, in many dialects. Thus a secondary purpose of this study is to examine how the temporal trajectories and formant frequencies of the dark lateral compare to its reflex, /w/.

2 Method

Five native speakers of Lower Sorbian (mean age 68; two male and three female) were recorded in a quiet room in Lower Lusatia, typically in villages surrounding Cottbus. Each participant was met at the most convenient location near their home (usually their home) and data recording occurred. All data was recorded using a Fostex FR-2 LE: Field Recorder and a Lavalier AT831b microphone at 44,100 Hz and 32-bits. Two speakers had a clear/dark contrast in their dialect and three speakers spoke a dialect where the dark lateral had undergone a sound change to /w/.

Participants repeated a corpus of real words that had the laterals and /w/ in word-initial (/l/: *lac* '(dim), vest, bib;' /ɫ, w/: *łakomy* 'sweet-toothed') and word-final (/l/: *belial* 'devil;' /ɫ, w/: *kał* 'sourkraut') positions. Due to the desire to compare the acoustics of the dark lateral with its reflex in other dialects, the same word was used to compare these two phonemes (in Lower Sorbian orthography, ł represents either a dark lateral or a bilabial glide, depending on the dialect). The target words were produced in a random order with distractor tokens. Each word was produced three times by each speaker for a total 30 tokens (3 repetitions of each word x 2 words x 5 speakers).

2.1 Analysis

Dynamic measures of F1 to F3 were taken at 10 equally spaced intervals for the entire lateral up to the temporal mid-point of the vowel. This resulted in an interpolated time for the dynamic measures analysis. Formant measure extraction was done using Praat [14] and were then normalized using a Lobanov correction [15] with the Vowels package [16] in R [17]. F2-F1 [11] was calculated by subtracting F1 from F2 at each interval of the dynamic measure. Formant measures were compared using a Smoothing Spline (SS)ANOVA [18, 19] in R [17].

3 Results

In this section, the results for the onset and coda analysis of the F1, F2, and F3 are presented first. Then the F2-F1 results are presented. In both cases the onset data is presented before the coda data.

Figure 1 presents the formant frequencies and trajectories for the laterals and /w/ in the onset position. F1 frequencies and trajectories were nearly identical across all target phonemes. The trajectory was steady throughout the duration of the consonant and the offset into the following vowel resulted in a sharp increase of F1. F2 frequencies for the dark lateral and /w/ overlapped, but the trajectories were quite different. /w/ started at a lower frequency and its trajectory was much sharper of an increase. However, it is important to note these differences do not appear to reach statistical significance. F2 for the clear lateral was much higher than the dark lateral and /w/ and had a gradual decrease in frequency over duration. F3 was the largest point of difference between the dark lateral and /w/: they both started at similar frequencies, but the dark lateral had a steady upwards trajectory, while /w/ had a sharp decrease in F3. The clear lateral had the highest F3 and exhibited a steady decrease over the duration.

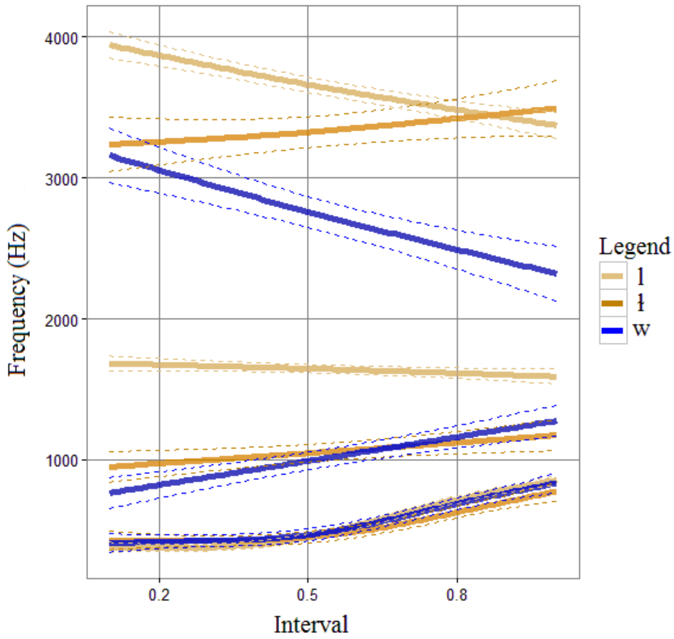

Figure 1: Formant frequency and trajectories for laterals and /w/ in the onset position.

Figure 2 presents the formant frequencies and trajectories for the laterals and /w/ in the coda position. F1 frequency and trajectory for the laterals were identical in the coda position and /w/ showed no significant difference. /w/ had a slightly different trajectory, starting a bit lower and stabilizing at a slightly higher frequency. F2 for the dark lateral was not significantly different from /w/, but the trajectories were again different. The dark lateral had a downward slope, while /w/ had an upward slope. F2 for the clear lateral remained relatively steady throughout articulation. F3 for the dark lateral and /w/ contrasted the onset results: both showed an identical upwards trajectory at a nearly identical frequency. The clear lateral also had an upwards trajectory, but at a lower frequency. However, this difference also did not reach statistical significance.

Figure 3 presents the formant frequencies and trajectories for the F2-F1 of the laterals and /w/ in the onset position. F2-F1 measures for the dark lateral and /w/ were not statistically different, but the trajectories differed. During the articulation of /w/, there was a gradual increase in F2-F1 and during the following vowel. However, for the dark lateral, the F2-F1 remained relatively steady throughout articulation and dropped for the following vowel. The results for the clear lateral showed that there was a relatively sharp drop throughout articulation which only sharpens through the following vowel.

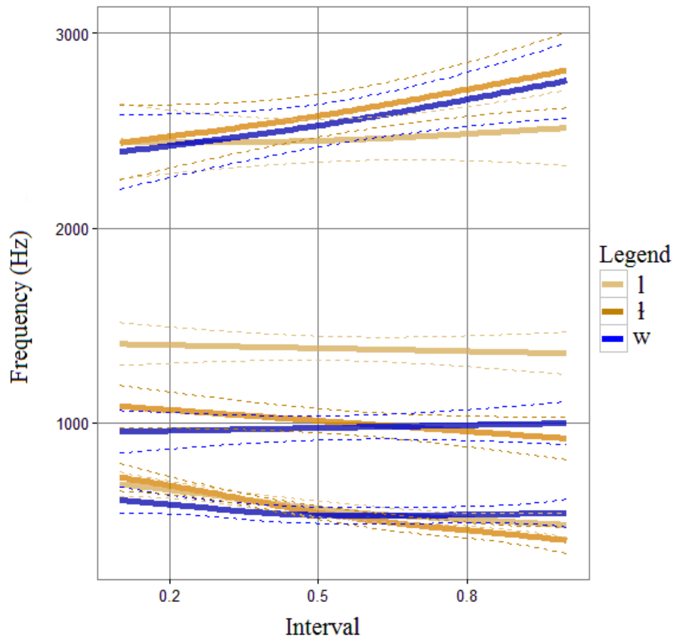

Figure 2: Formant frequency and trajectories for the laterals and /w/ in the coda position.

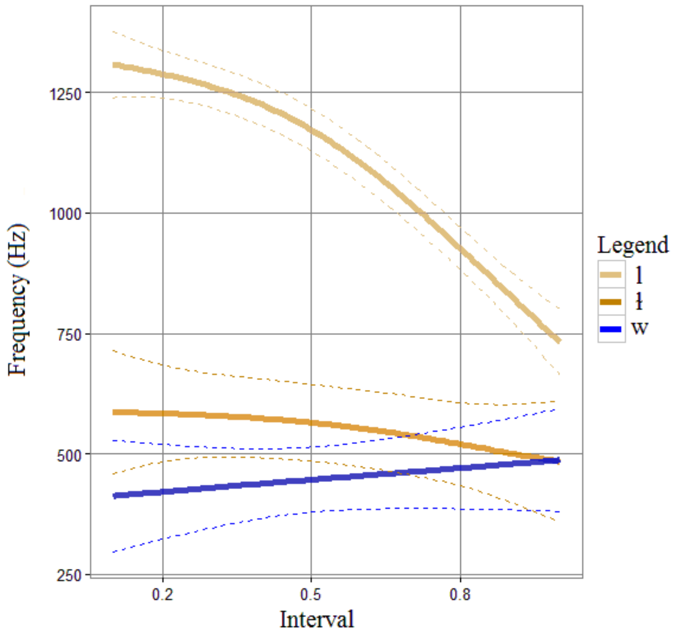

Figure 3: Formant frequency and trajectories for F2-F1 of the laterals and /w/ in the onset position.

Figure 4 presents the formant frequencies and trajectories for the F2-F1 of the laterals and /w/ in the coda position. F2-F1 measures for the dark lateral and /w/ were not statistically different, but the trajectories differed. During articulation of the vowel preceding /w/, there was a gradual decrease in F2-F1, and during the following /w/, F2-F1 increased over the duration.

However, for the dark lateral, the F2-F1 increased steadily through the preceding vowel and the lateral. The results for the clear lateral showed that there was a steady increase in F2-F1 throughout articulation and into the beginning of the lateral. However, unlike the other two phonemes, the lateral reached a clear target and maintained a steady F2-F1 almost throughout the entirety of its duration.

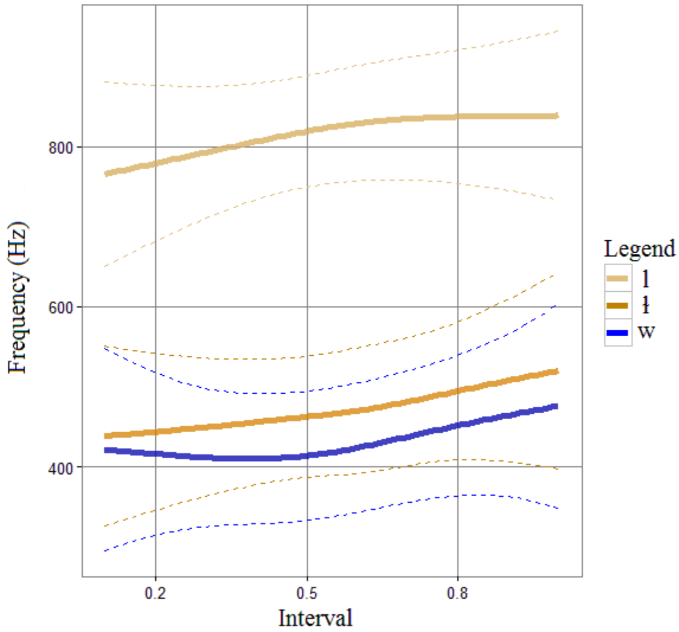

Figure 4: Formant frequency and trajectories for F2-F1 of the laterals and /w/ in the coda position.

4 Discussion

The dynamic trajectories and formant frequencies for the clear and dark lateral differed across word positions. In the onset position, F1 trajectory and frequency were nearly identical for both of the laterals. This likely reflects a rapid tongue tip gesture involved in the closure formation and lateral constriction formation which is likely present at the beginning of articulation and is present throughout the duration of each lateral. F2 is also quite stable for the clear lateral in the onset position, which may suggest simultaneous achievement of both the tongue tip and tongue dorsum gesture. F2 for the dark lateral steadily increase over the duration of the onset, suggesting the target for the dark lateral may not be completely met due to conflicting environmental factors. F3 trajectories and frequencies are completely different for both laterals, suggesting a difference in vocal tract shape and changes over time.

In the coda position, F1 trajectories and frequencies for the laterals are again nearly identical. However, in this position the trajectory is downwards instead of upwards. This may suggest a later tongue tip gesture than in the onset position, but it may also indicate increased tongue body height to form the lateral constriction. In either case, the gesture is achieved later than in the case of the onset position. F2 for the clear lateral is steady throughout articulation, suggesting that the tongue height remains stable throughout. This may suggest that there is simultaneous or nearly simultaneous achievement of both the tongue dorsum and tongue tip gesture. F2 is also much lower in the coda position, indicating that there is some degree of darkness for the clear lateral in coda position. The dark lateral has a slight decrease in F2 over the duration, which when taken in consideration with the F3 changes over time, suggest that there are constant tongue movements throughout articulation. This contrasts F3 for the clear lateral which remains relatively stable, although it does increase approximately 100 Hz from the midpoint of the vowel to the end of the lateral. The steady F3 for the clear lateral does suggest a relatively stable vocal tract shape.

The clear lateral showed a constantly decreasing F2-F1 over the duration of articulation in the onset position and a sharp drop throughout the vowel. This suggests a highly mobile tongue dorsum which continues to retract over the duration. This contrasts the dark lateral which maintains a steady F2-F1 over the duration of the lateral and only slightly retracts throughout the following vowel. This may suggest the influence that the tongue dorsum retraction for the dark lateral has on the following vowel. This observation is supported by the significantly lower midpoint of the following vowel after the dark lateral (~500 Hz vs. ~750 Hz). In the coda position, it is clear that the tongue dorsum reaches its target much sooner for the clear lateral than the dark lateral. This is evidenced from the stable F2-F1 which occurs roughly around the start point of the lateral. The F2-F1 for the dark lateral, on the other hand, increases throughout articulation and never reaches a steady point.

Finally, the comparison of the formants for the dark lateral and /w/ indicate a strong similarity in F1, F2, and F2-F1 across all word positions. In all positions, these formants were not significantly different from each other; however, the trajectories of the formants may differ slightly in some word positions. This suggests similar articulatory and perceptual characteristics for the two segments. They do differ drastically in F3, particularly in the onset position, which might suggest the presence of lip rounding for /w/. However, in coda position, the F3 difference vanishes. The similarity in F1 and F2 may have led a lenition of the tongue tip gesture for the dark lateral, which lead to the sound change from the dark lateral to /w/. A clear trigger for this may have been the coda position which has matching F3, likely from a weaker degree of lip rounding for /w/. Articulatory phonology [20] would also predict a weaker tongue tip gesture in the coda position. This weakness, accompanied with extremely similar F1, F2, and F3 for the dark lateral and /w/ may have triggered the sound change.

5 Conclusion

The formant frequencies and trajectories were examined for the clear and dark laterals in Lower Sorbian. The results suggest difference in the timing and formant trajectories based on syllable position. Strong similarities exist between the dark and clear lateral in Lower Sorbian, but there are still differences in timing, likely related to the degree of involvement of the tongue dorsum in the gestural constellation for each lateral.

Acoustic and articulatory similarities between the dark lateral and /w/ suggest that the sound change in some Lower Sorbian dialects from the dark lateral to a /w/ was caused by a lenition of the tongue tip gesture. This was likely caused by acoustic/perceptual similarities between the two segments. This similarity is intensified in the coda position which could have been the trigger for the change.

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References

[1] Ladefoged, P. & Maddieson, I. *The sounds of the world's languages*. Blackwells: Oxford. 1996.

[2] Maddieson, I. *Patterns of sounds.* Cambridge, England: Cambridge University Press. 1984.

[3] Narayanan, S., Alwan, A., & Haker, K. Toward articulatory-acoustic models for liquid approximants based on MARI and EPG data. Part I. The laterals. *Journal of the Acoustic Society of America*, 101(2), 1997, 1064-1077.

[4] Recasens, D., Fontdevila, J., & Pallarès, M. D. Velarization degree and coarticulatory resistance for /l/ in Catalan and German. *Journal of Phonetics*, 23, 1995, 37-52.

[5] Recasens, D. & Espinosa, A. Articulatory, positional and coarticulatory characteristics for clear /l/ and dark /l/: evidence from two Catalan dialects. *Journal of the International Phonetic Association*, 35(1), 2005, 1-25.

[6] Recasens, D. & Farnetani, E. Articulatory and acoustic properties of different allophones of /l/ in American English, Catalan, and Italian. In *Proceedings of the International Conference on Spoken Language Processing* 2, Kobe, 1990, 961-964.

[7] Straka, G. Contributions à la description et à l'histoire des consonnes L. Travaux de Linguistique et Littérature 6, 1968, 267–326.

[8] Giles, S. B. & Moll, K. L. Cinefluorographic study of selected allophones of /l/. *Phonetica* 31, 1975, 206-227.

[9] Browman, C. P. & Goldstein, L. Gestural syllable position effects in American English. In Bell-Berti, F. & Raphael, L. J. (eds.), *A Festschrift for Katherine Safford Harris*, Woodbury, NY, 19-34, 1995.

[10] Al-Ani, S. H. *Arabic Phonology*. The Hague: Mouton, 1970.

[11] Sproat, R. & Fujimura, O. Allophonic variation in English /l/ and its implications for phonetic implementation. *Journal of Phonetics* 21, 1993, 291-311.

[12] Gick, B., Campbell, F., Oh, S., & Tamburri-Watt, L. Toward universals in the gestural organization of the syllables: A cross-linguistic study of liquids. *Journal of Phonetics*, 34, 2006, 49-72.

[13] Krakow, R. A. Physiological organization of syllables: A review. *Journal of Phonetics*, 27. 1999, 23-54.

[14] Boersma, P. & Weenink, D. *Praat: Doing phonetics by computer* [Computer program]. Version 5.3.65 http://www.praat.org/, 2016.

[15] Adank, P., Smirts, R., & van Hout, R. A comparison of vowel normalization procedures for language variation research. *Journal of the Acoustic Society of America*, 116, 2004, 3099-3107.

[16] Thomas, E. R. & Kendall, T. *NORM: The vowel normalization and plotting suite.* http:ncslaap.lib.ncsu.edu/tools/norm, 2007.

[17] R Development Core Team. *R: A language and environment for statistical computing.* http://www.R-project.org/, 2016.

[18] Gu, C. *Smoothing spline ANOVA models*. New York: Springer, 2002.

[19] Davidson, L. Comparing tongue shapes from ultrasound imaging using smoothing spline and analysis of variance. *Journal of the Acoustic Society of America*, 120, 2006, 407-415.

[20] Browman, C. P. & Goldstein, L. F. Articulatory phonology: an overview. *Phonetica*, 49, 1978, 155-180.