THE RETROFLEX LATERAL [ɭ] AS AN ALLOPHONE FOR /l/ IN STANDARD AUSTRIAN GERMAN

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ABSTRACT

Standard Austrian German is assumed to have a single lateral phoneme /l/ realized as alveolar lateral [l]. However, a few studies report a retroflex articulation after back vowels in speakers from the city of Vienna. Since those reports are almost exclusively based on auditory assessment, this pilot study sets out to investigate the presence of retroflex laterals via formant analysis and Ultrasound Tongue Imaging (UTI). Six speakers from the cities of Vienna, Graz and Salzburg were recorded reading sentences containing target words with /l/ in word-final position in 9 different vowel contexts. Acoustic measures showed lowered F2 and F3 in the lateral after back vowels for all speakers. However, UTI results showed that only 3 speakers realize /l/ with a tongue-tip gesture typical for retroflex articulation after back vowels and /ɑː/. The remaining speakers realize alveolar [l] in all utterances. Consequences regarding the relation between acoustics and articulation are discussed.

Keywords: speech production, laterals, Austrian German, ultrasound tongue imaging

1. INTRODUCTION

Laterals are known as a diverse sound class in terms of acoustics and articulation [1]. Even for languages with a single lateral phoneme, often a variety of realizations are reported. One such case is German, including Austrian German, for which a single alveolar lateral /l/ is assumed [2, 3]. Based on the existing literature, /l/ after front vowels is realized as the "default" pronunciation [l], but after back vowels and /ɑ/ it has been suggested that it can be articulated as a retroflex [ɭ]. The present paper reports on a pilot study based on acoustic formant measurements and ultrasound tongue imaging (UTI) investigating the realization of postvocalic /l/ in Standard Austrian German (SAG).

A first report of a retroflex manner of articulation for /l/ after back vowels and labial sounds in Austria dates back to the beginning of the 20th century [4] for speakers in Vienna. A similar description is given in [5] for the speech of homeless people in Vienna recorded in the 1970s. Yet, these reports are solely based on auditory judgements. The question hence arises whether realizations of /l/ in certain vowel contexts can really be counted as retroflex, and specifically, whether such realizations are still found in present-day SAG as spoken by young and middle-aged speakers (<40 years of age). It also remains to be shown whether retroflex articulation is exclusive for SAG speakers in Vienna.

With regard to the acoustics and articulation of retroflex laterals, descriptions are mostly given for non-European languages in which a phonemic opposition between different laterals is found. As for their acoustic properties, alveolar laterals without any secondary articulation such as velarization or palatalization typically show an F2 around 1500-2000 Hz and F3 around 2500 Hz [6]. In contrast, a retroflex articulation tends to lower F3 such that it is close to F2 [7]. Similar values were reported in an acoustic and articulatory study on Tamil, a language with a phonemic contrast between dental /l/ and retroflex /ɭ/ [8]: Tamil /l/ is reported to have an F2 of around 1200 Hz and F3 around 2400 Hz; F2 for /ɭ/ is around 1460 Hz and F3 around 1800 Hz.

Articulatorily, laterals feature a lingual closure whilst leaving a lateral opening so air can still escape. The gesture for [l] is similar to alveolar plosives; retroflex [ɭ] is described to exhibit a rolling gesture along the alveolar ridge from back to front [8].

Next to those descriptions of the acoustics and articulation of laterals in general and retroflex manner of articulation in particular, a number of studies showed that the exact realization of laterals often depends on phonological context (e.g., [9]) and positional factors [10]; also, social conditioning has been reported [11]. However, studies on retroflex lateral allophony in European languages are rare.

The present study therefore sets out to describe the acoustics and articulation of the lateral phoneme /l/, and specifically the occurrence of allophonic retroflex articulation [ɭ] in young speakers from three cities in Austria (i.e., Vienna, Graz, Salzburg). As mentioned above, previous studies based on auditory descriptions of SAG suggest retroflex allophones in some phonological contexts in speakers of Vienna. The addition of speakers from two other regional centers allows us to test whether retroflexion is found in different local varieties of SAG or whether it is limited to speakers from Vienna. Overall, most

Austrians are assumed to be competent in a form of intended (regional) standard as well as a local dialect. Switching and shifting between varieties according to social and pragmatic circumstances is common [12], [13]. Since the present study set out to focus on SAG, the potential for varietal switching was minimized by using a sentence reading task [14].

2. METHODS

2.1. Participants

Six speakers were recorded acoustically and articulatorily using UTI. They were native speakers of Austrian German, between 26 and 38 years of age, one female and one male speaker from each of the cities of Vienna, Graz and Salzburg. They all grew up and had received a university degree in their city of residence. Unfortunately, the UTI recordings of the female speaker from Salzburg turned out to be unusable as the visual image of alveolar region appeared to be occluded by the lower jaw. Therefore, data from only 5 speakers will be reported. Recordings of additional speakers are planned.

2.2. Materials and Procedure

Nine German words were selected in which the lateral phoneme occurred word-finally in different vowel contexts (see Table 1). Preceding context covered the front vowels /iː/ and /ɛ/, the back vowels /uː/ and /oː/, the open vowel /ɑː/, the front rounded vowels /yː/ and /øː/ and the diphthongs /aɛ̯/ and /ɑɔ̯/. A following context was avoided by embedding the targets in carrier sentences in sentence-final position. For each target a semantically neutral and a semantically meaningful context sentence was constructed. The target words analyzed in this study were part of a larger set of 36 words serving different purposes.

Target	Translation	IPA
viel	*much*	/fiːl/
hell	*bright*	/hɛl/
steil	*steep*	/ʃtaɛ̯l/
fahl	*pallid*	/fɑːl/
Stuhl	*chair*	/ʃtuːl/
hohl	*hollow*	/hoːl/
Maul	*mouth (animals)*	/mɑɔ̯l/
Öl	*oil*	/øːl/
kühl	*cool*	/kyːl/

Table 1: List of items. *Target* gives the standard orthography; *Translation* the English equivalent; *IPA* the phonological transcription for SAG.

Recordings were made in soundproof booths at local research institutions. AAA software [15] was used for stimulus presentation and UTI recordings. A Telemed MC4-2R20S-3 ultrasound probe was fixed with an Ultrafit headset underneath the chin of the speaker to ensure the stability of the probe during the recording [16]. For the audio recordings a Røde M2 condenser microphone was placed in front of the participants and connected via a Scarlett Audio Interface to a laptop. Participants were asked to read the sentences off the laptop screen: first all targets in the neutral, then the semantically meaningful sentences. Both sets of sentences had to be read twice, resulting in four recordings per target. The recordings were followed by an interview to collect additional information about language use and the social background of the speakers, which is not reported here.

2.3. Data Preparation and Analyses

The phonetic realization of /l/ was annotated in AAA software [15] for the UTI data and in STx [17] for the acoustic analyses. Segment boundaries were marked by auditory judgment and visual inspection of the spectrogram. For the UTI recordings, splines marking the tongue contour were created using the batch processing function of AAA at every available frame of the sentences. For each item, after rectifying erroneous splines, a mean spline at the midpoint of the lateral over all 4 repetitions of the words was computed using the AAA workspace, exported as cartesian coordinates and visualized in R [18] [19].

For the acoustic data, the first three formants of the laterals were tracked automatically using the formant tracker of STx and manually corrected if necessary. Formant measurements in Hz were taken at 20 points evenly spread out across the duration of the /l/ and exported into a data table. The 5 middle points were used for analyses. Since F2, F3 and their relative position have been used most commonly to describe retroflexion, F2, F3 and the difference F3-F2 will be used for acoustic analyses.

3. RESULTS

3.1. Articulatory Data

The mean tongue splines of the UTI data were visualized to compare the position of the front part of the tongue. Retroflex tongue gestures should be discernible from alveolar ones by a higher and more posterior position of the tongue tip [8]. Fig. 1 shows the tongue contours for the 9 items averaged over the 4 repetitions for each speaker. Note that each item refers to a unique vowel context.

The male speakers from Vienna and Salzburg show very similar tongue contours for all 9 items. The tongue tip extends forward and is relatively low compared to the back of the tongue, suggesting a contact with the tongue blade in the alveolar region. The female speaker from Vienna and the two speakers from Graz show a higher and more posterior tongue tip position after /uː/, /oː/, /ɑɔ̯/ and /ɑː/ compared to the remaining contexts. This could suggest contact of the tongue tip in the postalveolar to palatal region. Critically, this equals the description of retroflex [ɭ] in Tamil [8].

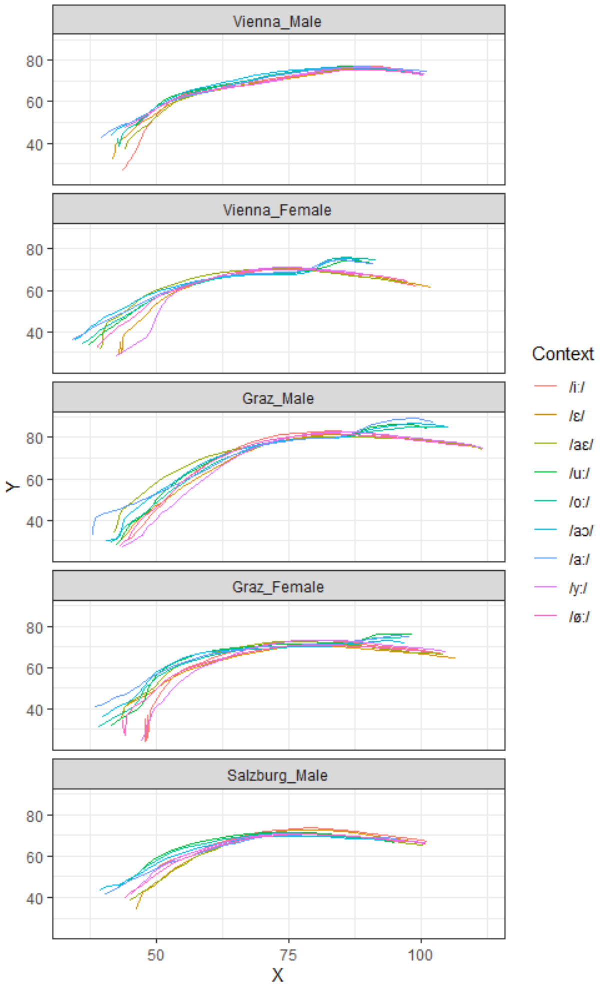

Figure 1: Mean tongue splines per vowel context for each speaker. X and Y refer to the cartesian coordinates as extracted from AAA. The tongue tip is on the right.

3.2. Acoustic Data

For a first assessment of the effect of phonological context on the laterals' formant values, items were grouped into 4 context conditions according to the frontness and rounding of the preceding vowels. /iː/, /ɛ/ and /aɛ̯/ were classified as front unrounded vowels, /yː/ and /øː/ as front rounded, /uː/, /oː/ and /ɑɔ̯/ as back and by default rounded. /ɑː/ was taken as back vowel without lip rounding. Analyses were conducted by first fitting a linear mixed-effects model with the difference between F3 and F2 in Hz as the dependent variable, Context Group as a fixed factor and Participant as a random factor. The model was then used to calculate pairwise comparisons of the context conditions using the emmeans() and pairs() functions of the emmeans package [20] in R [19]. Degrees of freedom were based on the Kenward-Roger method. P-values were adjusted by the Tukey method comparing 4 estimates. Table 2 shows the results.

Contrast	esti-mate	t.ratio	p
/ɑː/ - back	128	2.43	0.076
/ɑː/ - front	-349	-6.61	< 0.001
/ɑː/ - front round	-53	-0.92	0.794
back - front	-478	-12.6	< 0.001
back - front round	-181	-4.09	0.004
front - front round	296	6.68	< 0.001

Table 2: Statistics for the comparison of formant values (F3-F2 difference) of the laterals between the four types of contexts.

It appears that the formant values, and specifically the difference between F3 and F2, which, if low is typically taken as a measure of retroflexion, differ greatly between context conditions. Interpreting the estimates, it appears that the F3-F2 difference in the lateral is smallest after back (by default rounded) vowels followed by front rounded vowels. Laterals following /ɑː/ tend to pattern with rounded vowels.

Since, however, the articulatory data showed substantial differences between speakers in whether their tongue gestures suggest a retroflex articulation or not, also the acoustic data were inspected on an individual basis. In analogy to the tongue spline data, Fig. 2 illustrates F2 and F3 (in Hz) for /l/ in all items for each speaker. The straight solid line represents the hypothetical line where F2 and F3 would be equal.

Generally, after front (unrounded) vowels, where /l/ is articulated as alveolar by all speakers, the lateral expectedly shows relatively high F2 and F3 values and a rather large F3-F2 difference. In contrast, after back vowels, F2 and F3 as well as their difference are low for /l/ for all speakers and all contexts regardless of retroflex or alveolar articulation. Formant values of /l/ after front rounded vowels, where /l/ is always articulated alveolar, behave similarly to the back vowel context in the male speakers of Vienna and Salzburg. In contrast, in the female speakers they are closer to the front vowel and /ɑː/ contexts. This could explain the lack of difference in F3-F2 values between front rounded vowels and /ɑː/ in the statistical analyses. Finally, in the /ɑː/ context, when /l/ is retroflex in the speakers from Graz and the female speaker from Vienna, a high absolute F2 goes with a small F3-F2 difference. In the remaining two speakers, alveolar [l] after /ɑː/ patterns with front vowels.

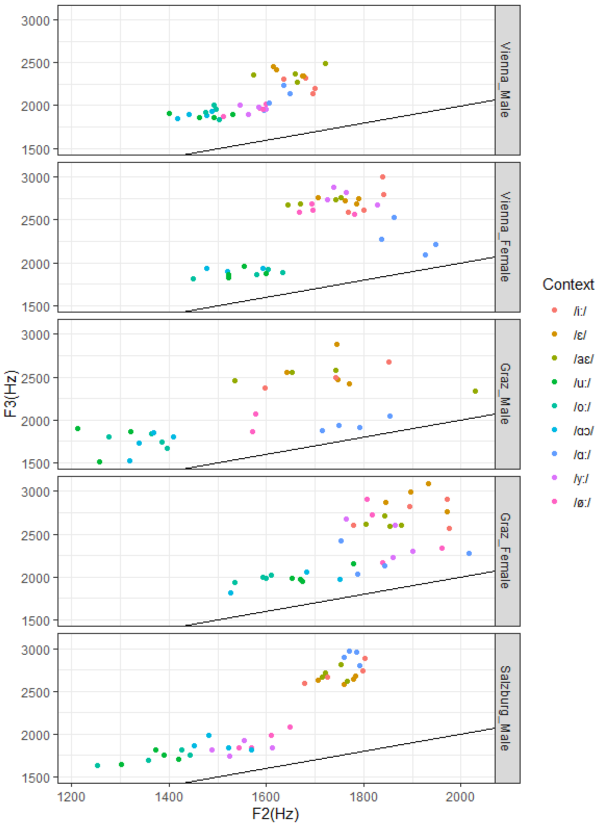

Figure 2: F2 and F3 values in Hz for all items/ vowel contexts per speaker. The grey line indicates the values where the formants would be equal.

3. GENERAL DISCUSSION

The aim of this study was to describe the articulatory and acoustic properties of /l/ in Standard Austrian German in word-final position and to investigate the potential occurrence of retroflex allophones in this position. Lateral productions in 9 vowel contexts from speakers from 3 cities were analyzed.

The articulatory analysis via ultrasound tongue imaging showed that three of five speakers articulated /l/ after back vowels and /ɑː/ as retroflex lateral [ɭ]. This was indicated by a high and relatively posterior tongue tip position. This contrasts with the alveolar articulation of /l/ after front vowels and front rounded vowels that show a relatively low and anterior tongue tip position. In the remaining two speakers, all laterals were found to be articulated as alveolar without any apparent gesture for retroflexion. The acoustic description encompassing F2, F3 and the difference F3-F2 shows less clear-cut results with individual patterns not fully matching expectations based on the articulatory data.

According to the literature, retroflex laterals are characterized by F2 and F3 being in close proximity to each other [8]. For the female speaker from Vienna and both speakers from Graz this assumption was confirmed: After back vowels and /ɑː/ when retroflex tongue gestures are produced, the difference F3-F2 (around 300 to 400 Hz) is much smaller compared to front and front rounded vowel contexts (roughly 600-1000 Hz). Additionally, after back vowels, absolute F2 and F3 values are lower compared to the /ɑː/ context. Curiously, the remaining male speakers from Vienna and Salzburg who according to the articulatory measures only produce alveolar laterals match the other speakers in their acoustic patterns of F2 and F3. Specifically, after front rounded and back vowels their *alveolar* laterals show a difference in F3-F2 similar to the *retroflex* laterals produced by the other three speakers in the same position.

These results may seem puzzling. Despite the difference in articulation visible in the UTI, alveolar and retroflex laterals showed acoustic similarities after back vowels in all speakers. A possible explanation would be that back vowels in German are articulated with the lips rounded, hence coarticulation may cause /l/ after back vowels to also be produced with rounded lips. Lip-rounding tends to lower F2 and F3 [7] and would explain the lower F3-F2 difference in /l/ after back vowels for the alveolar articulations. It would also explain the lower absolute F2 and F3 values in retroflex articulations after back vowels compared to the retroflexes after /ɑː/. However, a lowering effect of preceding lip rounding is absent after front rounded vowels in the female speaker of Vienna and less pronounced in the speakers from Graz. As a methodological consequence, future studies might need to additionally track lip rounding so as to disentangle the origin of lowered F2 and F3 in laterals after back vowels. Note however, that differences in articulatory gestures leading to the same acoustic and even perceptual consequences have been reported for other phones such as retroflexed vs. bunched rhotics in English [7].

From a sociolinguistic perspective, we can add to the existing descriptions of laterals in SAG that retroflexion, first of all, can be found in articulatory gestures as shown by the UTI data. Moreover, it is not exclusive for speakers from Vienna, since retroflex tongue gestures could be shown for the two speakers from Graz. Recording additional participants will show whether the differences found in this pilot study are speaker-specific or whether broader patterns dependent on region, gender or other social factors can be observed.

4. ACKNOWLEDGEMENTS

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