LABIALIZATION IN AMAZIGH: ACOUSTIC AND ARTICULATORY MARKING OVER TIME

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ABSTRACT

Labialization is the most widely distributed secondary articulation in the world's languages, however, literature on its phonetic properties is rare. This study provides an analysis of acoustic and articulatory markings of labialization in Tashlhiyt Amazigh. We present speech production data from six native speakers producing a set of plain and labialized dorsal consonants in [aCa] sequences. Formant trajectories of the vowels surrounding the consonants are analyzed as well as articulatory trajectories of the lip aperture and the tongue during the consonantal movements. In the acoustic domain, the Bayesian spline regression analysis reveals a lowering of F2 in the vowels adjacent to labialized consonants. In the articulatory domain, lip protrusion and tongue retraction are the primary articulatory correlates for labialization. Taken together these results suggest that labialization in Tashlhiyt is an instance of labio-velarization.

Keywords: Secondary articulation, labialization, acoustics, articulation, Amazigh

1. INTRODUCTION

Labialization is a secondary articulation that is mainly produced by a protrusion of the lips [1]. It is the most common secondary articulation in the languages of the world and patterns, most often with velar and uvular stops and fricatives [2]. Labialization has been addressed in the phonological literature to some extent, but detailed phonetic investigations of labialization are quite rare. In this study, we provide an analysis of labialization in Tashlhiyt, a language where the entire set of its dorsal stops and fricatives /g, gː, k, kː, q, qː, ʁ, ʁː, χ, χː/ has labialized counterparts /g^w, g^wː, k^w, k^wː, q^w, q^wː, $ʁ^w$, $ʁ^w$ː, $χ^w$, $χ^w$ː/.

1.1. Tashlhiyt Amazigh

Tashlhiyt is one of the three Amazigh varieties spoken in Morocco [3]. Its linguistic system is well-described, including its phonetics and phonology (for a review, see [4, 5]). Labialization is a lexical property of dorsals in Tashlhiyt (e.g., /ik^{w}la/ 'he was colored' vs /ikla/ 'he spent the day', /ʁi/ 'here' vs /ʁ^{w}i/ 'catch'). The phonology of labialization in Tashlhiyt has received much scholarly attention [6, 7, 8, 9], but data on the phonetics of the plain/labialized distinction is lacking. The aim of this study is thus to fill this gap, by providing a first analysis of acoustic and articulatory correlates of labialization over the time course of [aCa] sequences in Tashlhiyt.

1.2. The phonetics of labialization

Labialization is mainly produced by the addition of a lip protrusion gesture to a primary gesture [10]. It can be subcategorized into (a) simple labialization that involves an additional lip rounding gesture, and (b) a more complex and more common labio-velarization, produced by the lip protrusion plus a raising of the tongue dorsum [1]. Further, [1] mentions a timing asymmetry, where the location of the labialization gesture concentrates at the release of the primary gesture. For Moroccan Arabic, where labialization is considered a substratum from Amazigh [11, 12], articulatory data of plain and labialized dorsals showed a higher and more protruded lip movement as well as a backward movement of the tongue [13, 14].

Regarding acoustics, the most important information is reported to be on the surrounding vowels, as is the case for secondary articulations in general [1]. Specifically for labialization, a lowered F2 has been reported [13, 14, 15, 16, 17]. Further, [15] reports a lowering of the first formant in Nootka, while [13, 14] observed no significant changes in F1 in general comparing plain and labialized dorsals in Moroccan Arabic.

2. METHODS

2.1. Recordings and speech material

Acoustic and articulatory data were recorded from six native male speakers of Tashlhiyt (32-50 years, mean=44, sd=7) using the EMA AG 501 (Carstens Medizinelektronik GmbH). Sensors were placed on the upper and lower lips (ULIP, LLIP), the tongue tip (TTIP), the tongue mid (TMID) and the tongue body (TBO). Sensor positions were recorded with a sample rate of 1250 Hz and were filtered afterwards with a Butterworth low pass filter (cutoff frequency: 20 Hz, order 5). The acoustic signal was recorded with a head-mounted microphone at a sample of 44.1 kHz and 16 bit resolution.

The speech material presented here consists of [aCa] sequences that contained plain and labialized consonants, spoken in isolation. These sequences represent the pronunciation of indiviual letters in Tifinagh, the Amazigh alphabet. For instance, the letter <ⵣ>, which corresponds to the Latin letter <z>, is pronounced as [aza]. Consonants differ in place/manner, voicing and length (see Table 1). The stimuli were presented on a computer screen placed in front of the speakers. 271 tokens in total went to the analysis.

	length	
place	singleton	geminate
velar	g, k, gʷ, kʷ	gː, kː, gʷː, kʷː
uvular	ʁ, χ, ʁʷ, χʷ	ʁː, χː, ʁʷː, χʷː

Table 1: Plain and labialized target consonants.

2.2. Measurements

The acoustic boundaries of the vowels and target consonants were labeled in Praat v6.3.02 [18]. Formant frequencies were measured in steps of 10% across the preceding and following V. In the articulatory domain, the sensor positions of the upper and lower lips (ULIP, LLIP), the tongue tip (TTIP), the tongue mid (TMID) and the tongue body (TBO) in the front-back and low-high dimensions were measured in 10% steps from the beginning to the end of each segment in the [aCa] sequences. Lip aperture (LA) was calculated as the Euclidean distance between ULIP and LLIP. Acoustic measurements were done using Parselmouth v0.4.1 [19], which includes Praat v6.1.38, and a custom script written in Python v3.10.6 [20] was used for the measurements of the sensor positions.

2.3. Statistical analysis

Bayesian spline regression analysis was performed for the acoustic and articulatory trajectories using PYMC v.5.0.1 [21]. Separate models were fitted for the first three formants in the preceding and following vowels and for LA and TTIP, TMID and TBO sensors in the front-back and low-high dimensions. The model structure was the same for all trajectories: TYPE (plain, labialized), PLACE (velar, uvular), VOICE (voiced, voiceless), LENGTH (singleton, geminate) and the interactions of TYPE with PLACE, VOICE and LENGTH were population level effects and an additional spline term for TYPE and Time. SPEAKER was added as random intercept. Weakly informative priors were used for each model. Sampling consisted of four chains with 4000 samples for tuning and 400 samples for draws, resulting in a total of 16000 samples. The HDI+ROPE decision rule [22] was used to reject the null hypotheses. ROPEs were defined as the interval $\pm$0.1*SD for each response variable. Evidence for an effect was determined, if 95% Credible Interval (CI) of the posterior distribution was outside the ROPE.

3. RESULTS

3.1. Formant trajectories

The mean formant trajectories are shown in Fig. 1 (plain as solid lines and labialized as dashed lines). The trajectories of F1 in the labialized productions are slightly lower in both vowels. This effect seems to be stronger in the following V and stronger for uvular Cs. For both vowel positions (ROPEs: prec. V: $\pm$13, foll. V: $\pm$12), the regression results revealed evidence for an effect of PLACE (prec. V: β=135 [123,147], foll. V: β=71 [61, 81]), and the interaction TYPE and PLACE (prec. V: β=-32 [-50, -15], foll. V: β=-33 [-45, -18]) on F1. Only in the following V we found an influence of TYPE (β=-34 [-49, -20]) and VOICE (β=28 [18, 38]).

The trajectories of F2 show a clear lowering in the labialized contexts. This difference appears to be strongest in the first portion of the following V across place, voicing and length and in particular in Vs surrounding velars. Regression results for both Vs (ROPEs both $\pm$27) revealed evidence for F2 being influenced by TYPE (prec. V: β=-259 [-287, -231], foll V: β=-360 [-389, -333]), PLACE (prec. V: β=-273 [-293, -253], foll V: β=-232 [-251, -213]) and the interaction of TYPE and PLACE (prec. V: β=187 [157, 216], foll. V: β=185 [156, 213]).

The trajectories of F3 show very small and less clear differences. We found evidence for an influence of PLACE in both Vs (prec. V: β=191 [173, 209], foll V: β=182 [166, 198]), but in the following V, we observed also an effect of TYPE (β=-63 [-86, -40]) (ROPEs both $\pm$30).

Differences between the plain and labialized

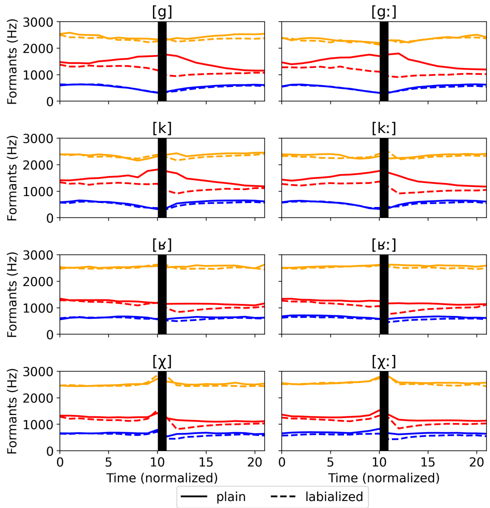

Figure 1: Averaged formant trajectories (F1: blue, F2: red, F3: orange) in surrounding Vs for singletons (left) and gemiantes (right). Black bars mark the C boundary.

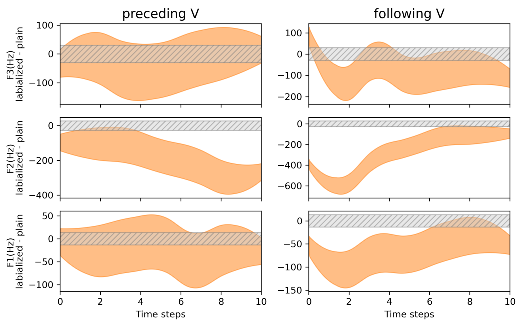

Figure 2: Labialized - plain differences (95% CI of the posterior) by formants and positions. Grey hatched areas indicate the respective ROPEs.

formant trajectories are depicted in Fig. 2. A short portion of F3 at the beginning of the following V and the first half of the F1 trajectory in the following V were outside the respective ROPEs. Strong evidence for a difference between plain and labialized productions in F2 was found for the most part of the surrounding vowels, with the highest difference near the beginning of the following V.

3.2. Articulatory trajectories

The trajectories for the LA are depicted in Fig. 3 and the trajectories for the tongue sensors are shown in Fig. 5. The time points 10 and 20 correspond to the acoustic C segment. Regarding LA, lips were more closed for labialized Cs than for plain Cs. For the labialized productions, the trajectories lowered continuously towards the C's mid as the region of its minimal aperture and raised to the end of the following V. Regression results showed evidence for TYPE (β=-3.2 [-3.5, -2.9]), PLACE (β=1.2 [0.96, 1.4]) and their interaction (β=-1.1 [-1.4, -0.8]) (ROPE $\pm$0.65).

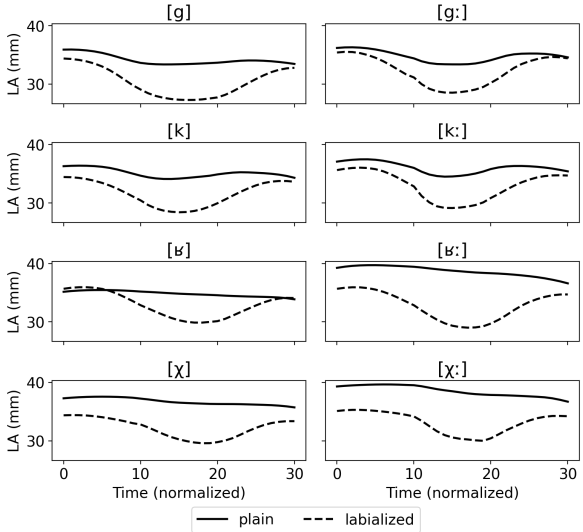

Figure 3: Averaged LA trajectories (plain: solid, labialized: dashed) by consonant (rows) and length (columns).

The difference for LA between labialized and plain trajectories is presented in Fig. 4. The largest portion of the 95% CI of the posterior is outside the ROPE, indicating evidence for a lowered LA in the central region. The highest difference can be found in the mid of C movement with a posterior mean of -6 mm.

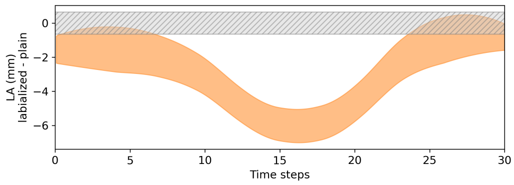

Figure 4: Labialized - plain difference (95% CI of the posterior) for the LA trajectory. The grey hatched area indicates the ROPE.

Coming to the tongue movement, it can be observed from Fig. 5 that the trajectories of labialized productions display a backward movement across place, voicing and length, with the exception of [χ:], where a slight fronting can be observed. The tongue in the low-high dimension may be lowered for labialized C (e.g., [g^w:, k^w]) or (slightly) raised (e.g., [g^w, χ^w]).

In the front-back dimension, ROPEs were set to

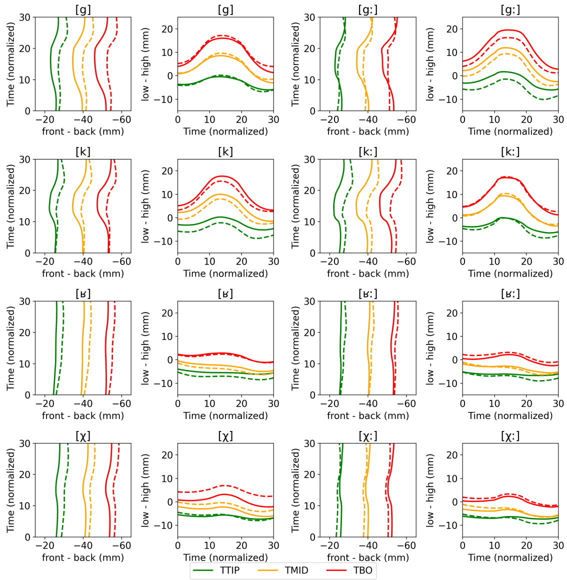

Figure 5: Averaged tongue sensor trajectories of plain (solid) and labialized (plain) productions for each C (rows) and length (singleton: first two columns, geminates: last two columns).

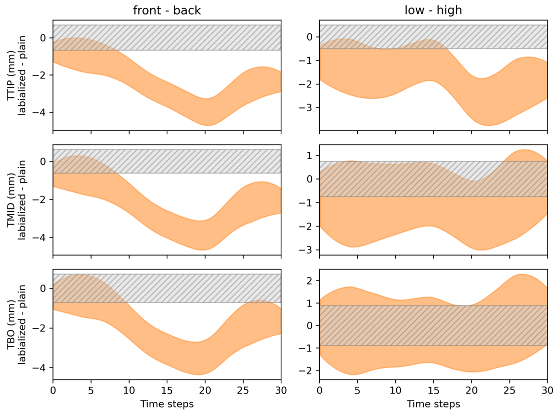

Figure 6: Labialized - plain differences (95% CI of the posterior) by tongue sensors and dimensions. Grey hatched areas indicate the respective ROPEs.

±0.68 for TTIP, ±0.62 for TMID and ±0.71 for TBO. We found evidence for an influence of TYPE on all tongue sensors (TTIP: β=-2.9 [-3.2, -2.7], TMID: β=-3 [-3.2, -2.8], TBO: β=-2.9 [-3.1, -2.6]) and PLACE (TTIP: β=-1.3 [-1.5, -1.2], TMID: β=-2.6 [-2.7, -2.4],TBO: β=-2.8 [-3, -2.7]), and their interaction (TTIP: β=1.2 [0.99, 1.4], TMID: β=1.6 [1.4, 1.8], TBO: β=1.9 [1.7, 2.2]). Regarding the low-high dimension, the regression models showed evidence for an effect of PLACE in every sensor (TTIP: β=-2.7 [-2.9, -2.5]; ROPE ±0.5; TMID: β=-6.5 [-6.7, -6.2], ROPE ±0.74; TBO: β=-8.2 [-8.5, -8,0], ROPE ±0.89). An influence of TYPE was observed for the TTIP only (β=-1.8 [-2.1, -1.6]).

Fig. 6 depicts the differences between the labialized and plain trajectories. The majority of the differences in the front-back dimension of TTIP, TMID and TBO fell outside the ROPEs, indicating a backing of the tongue for labialized productions. The points with the highest differences were towards the acoustic end of the consonant (around time step 20). In the low-high dimension, only the second half of the TTIP was outside the ROPE, indicating evidence for a lowering of the tongue tip in the second half of the C movement.

4. DISCUSSION AND CONCLUSION

This study investigated the acoustic and articulatory marking of labialization over the time course of Tashlhiyt [aCa] sequences.

The acoustic results showed a lowering of F2 as the primary acoustic correlate for labialization, similar to the findings in [13, 14] for Moroccan Arabic. The highest difference in F2 was found at the beginning of the following V. However, we also observed a slight lowering of F1 in the following V. Regarding articulation, we found a lip protrusion with the strongest closure of the lips near the mid of the C movement for labialized productions. In addition, a retraction of the tongue during the labialized Cs was observed and this difference was strongest near the acoustic end of the Cs. We also found a slight raising of TTIP in the second half of the C, which may be a result of more flexibility for this articulator since the primary articulator for dorsals is the tongue dorsum.

As the data presented here showed strong evidence for lip protrusion plus a retraction of the tongue, labialization in Tashlhiyt can be considered as labio-velarization [1, 13]. This combination of lip aperture and tongue retraction is most probably what triggers the important lowering of F2 for labialized Cs: Following [23], F2 lowering can be attributed to a backward movement of the tongue and also lip protrusion together with a dorsal constriction.

This preliminary study is a small part of a larger corpus of research. In the future, the study will be expanded to include more items, different word positions and a wider range of vowels. The aim is to provide a more comprehensive understanding of the phonetics of labialization in Tashlhiyt.

5. ACKNOWLEDGEMENTS

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