Exploring Voicing Contrast in Western Armenian: A Language Contact Case Study

I – Introduction and Language Overview

The literature on Western Armenian ("WA") has described it as having a two-way contrast between voiceless aspirated plosives and affricates, and their voiced counterparts. This study investigates whether language contact will have an effect on WA voice-onset timing ("VOT") production in the case of trilinguals in Québec, Canada, statistically analyzes our experimental data, briefly explores language contact effects and various complicating factors which seem to increase or decrease resistance to VOT change, and compares our results with those found in other WA phonetic studies with participants who had different dominant language backgrounds. Our hypothesis is that there will be a statistically significant effect on WA VOTs due to English influence.

Armenian is a distinct branch in the Indo-European language family, spoken by roughly six million people (though estimates vary wildly for the number of Western speakers, from 60,000 to 1.5 million). Other than the 5th century Classical variant, there are two main modern varieties of Armenian: WA, based on the spoken dialect of modern-day Istanbul and spoken today by diaspora descendants across small communities in Europe, the Americas, and Australia, and Eastern Armenian ("EA"), based on the spoken dialect in Yerevan, which is today the official language of the Republic of Armenia Mutually intelligibility is limited between the two, as there are significant differences in the lexicon, morphosyntax, and phonology. Most relevant for phonetic research, historically Armenian used a three-way voicing contrast (voiceless aspirated, plain voiceless, and voiced) for its stops and affricates – EA has essentially kept the Classical system (Khachaturian 1983, 1988), while WA devoiced and aspirated all previously voiced stops and affricates (thus merged all Classical voiced stops and affricates with voiceless aspirated ones, which it kept intact) and voiced all previously plain voiceless stops and affricates, resulting in only a two-way contrast.

	I voiced aspirated	II voiceless voiced	III aspirated aspirated
	Բ	Պ	Փ
Eastern Armenian	[b]	[p]	$[p^h]$
Western Armenian	$[p^h]$	[b]	$[p^h]$
	Գ	Կ	Ք
Eastern Armenian	[g]	[k]	$[k^h]$
Western Armenian	$[k^h]$	[g]	$[k^h]$
	Դ	Տ	Թ
Eastern Armenian	[d]	[t]	$[t^h]$
Western Armenian	$[t^h]$	[d]	$[t^h]$
	Ձ	Ծ	Ց
Eastern Armenian	[dz]	[ts]	$[ts^h]$
Western Armenian	$[ts^h]$	[dz]	$[ts^h]$
	Ջ	Ճ	Չ
Eastern Armenian	[dʒ]	[tʃ]	$[tʃ^h]$
Western Armenian	$[tʃ^h]$	[dʒ]	$[tʃ^h]$

Figure 1 – Stop and affricate voicing differences between the two dialects

<u>II – Literature Review</u>

The vast majority of linguistic research has been conducted for the EA and Classical varieties (Hübschmann 1897, Meillet 1936), and comparatively scanty material exists for the Western dialects. There have only been two acoustic studies for WA, one concentrating on vowel production in California heritage WA speakers (Godson, 2004) and the other by Kelly & Keshishian (2019) which we will explore in greater depth since it focused on VOT.

There are several phonetic studies on EA – the earliest appears to be Adjarian (1899) though in the English-speaking world, it was Lisker & Abramson (1964)'s classic study on EA which distinguished the three-way contrastive stops solely in terms of VOT, which was mapped on to voiced, voiceless unaspirated, and voiceless aspirated categories.

The second study that bears mentioning is by Hacopian (2003), who set out to examine the effect of prosody on VOT of the three-way bilabial stop contrast. Her research questions led her to investigate how the realization of this three-way contrast is affected by the particular prosodic domain in which stop consonants are final (since the maintenance of syllable- or word-final three-way contrasts are crosslinguistically rare (Khachaturian 1988; Ladefoged & Maddieson 1996; Vaux 1998)), and how this realization is affected by the voicing of the following sound or the lack of a following segment. Though she had a sample of merely 3 speakers of Tehran EA, a subdialect, she found that the three-way stop VOT contrast is maintained word-finally – all three speakers made significant VOT distinctions between target consonants within the same boundary condition, and there were no differences among the speakers. More specifically, it was found that the three-way contrast is preserved in various prosodic domains in which the stop consonants are final, and that this contrast is maintained such that larger prosodic domains had longer VOT values for all speakers, and this finding was unaffected by the voicing of the following sound. Furthermore, closure duration and burst amplitude did not factor into the distinction of the three-way VOT contrast.

The third study is by Seyfarth & Garellek (2018), which differs from Lisker & Abramson (1964) in its details, with 8 speakers of Yerevan Armenian (the main prestige Eastern variety). It focused on the acoustics of the three-way stop contrast in EA and found that voicing strength, VOT, and aspiration were significantly different among all three stop categories, albeit the differences were small, though what is most interesting is that the phonologically voiced stops had a breathy voice phonation to them (Baronian 2017) – their study was meant to to converge on a description of how voice quality is involved in the contrast in EA and they demonstrated how voice quality can be assessed in a two-dimensional acoustic space using a spectral tilt measure in conjunction with a measure of spectral noise. Furthermore, for the voiceless unaspirated plosives, most speakers produced acoustically modal voiceless plosives, although two out of eight showed evidence for some glottal constriction and tensing. These findings complement the proposition that despite the descriptive power of VOT, it may not account for all phonetic aspects of the voicing distinction – the phonetic and phonological nature of laryngeal contrast in voicing may be incomplete without looking into other phonetic properties that may co-occur with VOT (Cho, Whalen & Docherty 2019).

The only VOT study on the Western variety, by Kelly & Keshishian (2019), explored the acoustic correlates of voiced and voiceless aspirated stops and affricates in word-initial and word-medial position among 8 speakers in Lebanon. All participants were also native speakers of Lebanese

Arabic (which, like French, has a pre-voiced vs. unaspirated voiceless contrast). The study found that the participants had voiced and voiceless affricates and stops, with affricates having shorter aspiration than stops. Voiced stops were found to be pre-voiced, and aspirated voiceless stops were more accurately described as unaspirated, since the authors found that their VOT measurements were short; these results, the authors suggest, may be due to native Lebanese Arabic influence. Interestingly, unlike studies conducted on affricates in other languages such as Nepali (Clements & Khatiwada 2007) and Ixcatec (DiCanio 2011), where word-initial affricates had longer duration of closure, frication, and aspiration than word-medial ones, the Kelly & Keshishian (2019) study showed that word position did not have a significant effect on any measures, in relation to both affricates and stops.

More generally, the literature has found that those for whom English became dominant in early childhood are likely to show a greater influence of English on their heritage language than individuals who were first exposed to English as adults (Caramazza et al. 1973, Labov 1981, Labov 1982, Andersen 1989). However, there are complicating factors in these contact-induced changes (Nagy & Kochetov 2013), such as social and extralinguistic factors (individual and community levels of self-preservation, institutional support, assimilation pressures, etc.), which appear to have uneven effects on intergenerational VOT measurements, at least for the Russian, Ukrainian, and Italian heritage speakers in Toronto examined by Nagy & Kochetov 2013 study.

Regarding the VOT of minority languages in English-dominant areas, there is a fairly large number of studies documenting English influence on VOT for French in Canada (Hazan & Boulakia 1993, Hannahs 2007, Netelenbos, Li & Rosen 2016). Hazan and Boulakia (1993) investigated the production of VOT in bilabial stops by bilingual English and French speakers who differed in language dominance. Their main finding was that despite proficiency in their L2, bilingual speakers produced a voicing pattern in their L2 that was based on the voicing pattern of their L1 (MacLeod & Stoel-Gammon 2010) – thus there is a case to be made that sequential bilinguals who learned both languages in childhood show a unidirectional influence of their L1 on L2, and that this pattern appears to hold true for simultaneous bilinguals in contexts where one language is the sociopolitically dominant one, the other being the heritage language (Tse 2019). Still within the Canadian context, it has also been shown that among native French speakers who were bilingual in English, their L2's VOT were produced in a manner resembling that of French (Turner et al. 2014).

III – Experiment Design

i) – Participants

Participating in this study are six WA speakers who learned English and French before age 8, and whose English is native-like and dominant (used every day professionally and personally). Two out of the six are also native EA speakers due to having one parent from the former Soviet Union, but quickly acquired WA since they both were active members of the Armenian community in Québec. All six use WA at least several times per week in familial and personal usage domains, and all six are fluent speakers of Québec French, though they are all English-dominant as adults. Both bidialectal speakers were carefully instructed to only speak using the Western dialect. One speaker was more French-dominant during childhood. In order to minimize gender and large age gap effects, all of the participants are male and aged between 29 and 38.

ii) – Description of stimuli

Word-initial, -medial, and -final VOT was measured using recordings from oral reading of a list of words (attached as an Appendix), without carrier sentences, all written in Armenian script. There are five different words (all of them real and most of them are commonly used – we will revisit the issue of less-familiar words), each repeated once, for all possible combinations of sound position (initial, medial, and final), place of articulation (bilabial, dental, and velar for plosives, and alveolar and post-alveolar for affricates), and voicing (nominally voiced and voiceless aspirated), for a total of 150 words, for a total of 900 tokens. To neutralize the effects of vowels, the surrounding vowel remains a low back unrounded [ɑ] throughout. The IPA-based transcription given in the word list below represents the phonological category of the consonants in question. Note that WA has a mild word-final stress on all prosodic elements save for a very restricted set of bound suffixes (not featured in the wordlist), though there is no vocalic reduction and all lexical items' syllables have similar duration. Also note that because there are no carrier sentences, the VOT values are likely to be slightly higher than expected, though the participants were instructed to read at a normal pace – there was usually less than a second of empty time between each utterance.

Voicing	Place	Tokens		
		initial	final	medial
voiced	bilabial	30	30	30
	dental	30	30	30
	velar	30	30	30
	alveolar	30	30	30
	post-alveolar	30	30	30
voiceless	bilabial	30	30	30
	dental	30	30	30
	velar	30	30	30
	alveolar	30	30	30
	post-alveolar	30	30	30

Table 1 – Frequencies of tokens based on voicing and place of articulation.

iii) – Procedures

Participants were told to record themselves with 44.1kHz-capable headset in a quiet room, saved in .wav file format. Though the bitrate is slightly different for each of the .wav files received, they were all at least 705 Kpbs, which is more than sufficient for acoustic analysis. The sentences were presented in the Armenian script via electronic means, with each sound in a block together. They were told to read each word in their speaking voice and at a normal pace, taking breaks wherever necessary.

iv) – Measurements

Target words were labelled in Praat for whatever was present among the following: closure, burst, and aspiration, which counted as positive VOT. VOT was calculated for voiced sounds as the duration of voicing during the closure until release, and for voiceless sounds as release burst plus aspiration. Similar but not identical to Kelly & Keshishian (2019), our independent variables were: voicing (voiced vs. voiceless), place of articulation (bilabial, dental, velar for stops, and alveolar and post-alveolar for affricates), and sound position (initial vs. medial vs. final). The measures were subjected to a few types of linear regression analyses, among other statistical tools such as ANOVA, to determine if they were affected by the independent variables.

v) – Other remarks

The duration of the segments was recorded using a script previously used in this class, and the data was extracted and elaborated in LibreOffice Calc, and the statistics software used was a combination of Jamovi (https://www.jamovi.org/) and Jasp (https://jasp-stats.org/). To a minor extent, we cleaned up the data – one speaker read the wordlist in the wrong order, so all the labelling had to manually be redone. We also cleaned up the spreadsheet data due to some formatting errors from the .txt file to .csv, such as blank cells or mismatched columns. Luckily, there was no rejected data.

IV – Results and Analysis

In this section, we will discuss the main results while addressing some of the points made in the sections above. The measurements and their mean values are listed the attached spreadsheet – the master tab contains all the raw data used in this experiment, and the generically-labeled tabs (sheets) represent the different calculations made for specific sound groups or speakers (and the differently spliced versions of the data). Basic statistics along with a few more advanced results will be shown, along with providing tables and figures with the necessary descriptive statistics to make sense of the data.

Position	Place of articulation	mean (ms)	Std. error mean	median (ms)	mode (ms)	Range (ms)	Min. (ms)	Max. (ms)	Std. deviation	Skewness
initial	bilabial	82.1	**5.31**	76.5	41.0	**203**	**16.5**	219	41.1	0.823
	dental	82.6	4.71	78.6	31.0	161	16.9	178	36.5	0.430
	velar	81.5	4.53	86.6	32.1	127	24.2	151	35.1	-0.240
	alveolar	**127**	4.76	**118**	**62.0**	176	59.7	**236**	36.9	0.421
	post-alveolar	115	4.34	115	122	176	49.4	225	33.6	0.688
final	bilabial	87.7	4.75	88.8	97.5	210	**15.8**	226	36.8	0.544
	dental	102	4.53	96.1	66.2	163	21.4	184	35.1	0.149
	velar	103	4.73	104	71.6	172	17.7	190	36.6	-0.0614
	alveolar	**171**	**8.53**	**189**	**170**	**268**	23.3	**292**	**66.1**	-0.505
	post-alveolar	166	7.00	169	44.7	239	28.9	268	54.2	-0.484

medial	bilabial	64.4	2.62	63.3	50.7	103	**16.8**	120	20.3	0.523
	dental	57	2.58	52.6	51.9	110	22.4	132	20.0	1.39
	velar	56.5	2.67	53.6	49.6	101	19.6	121	20.7	1.04
	alveolar	**93.7**	**3.59**	**88.9**	**72.7**	**126**	45.6	**171**	27.8	0.574
	post-alveolar	76.6	2.50	75.1	67.6	102	31.0	133	19.4	0.307

Table 2 – All durations and relevant descriptive statistics by place of articulation (voicing merged). Greatest values by position in bold (except for minima).

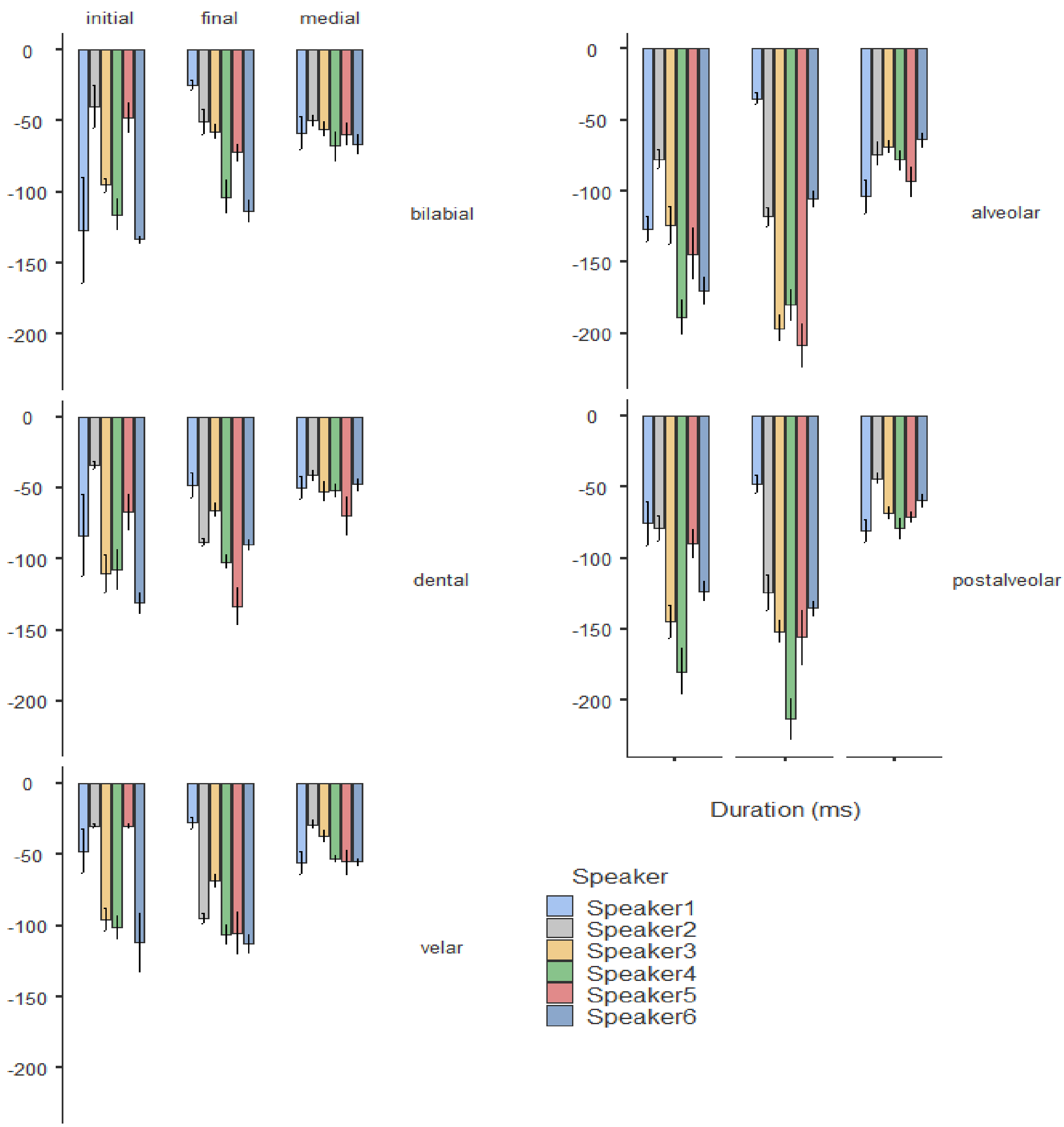

Figure 2: A visual speaker-by-speaker bar representation of voiced VOT means with quartile lines.

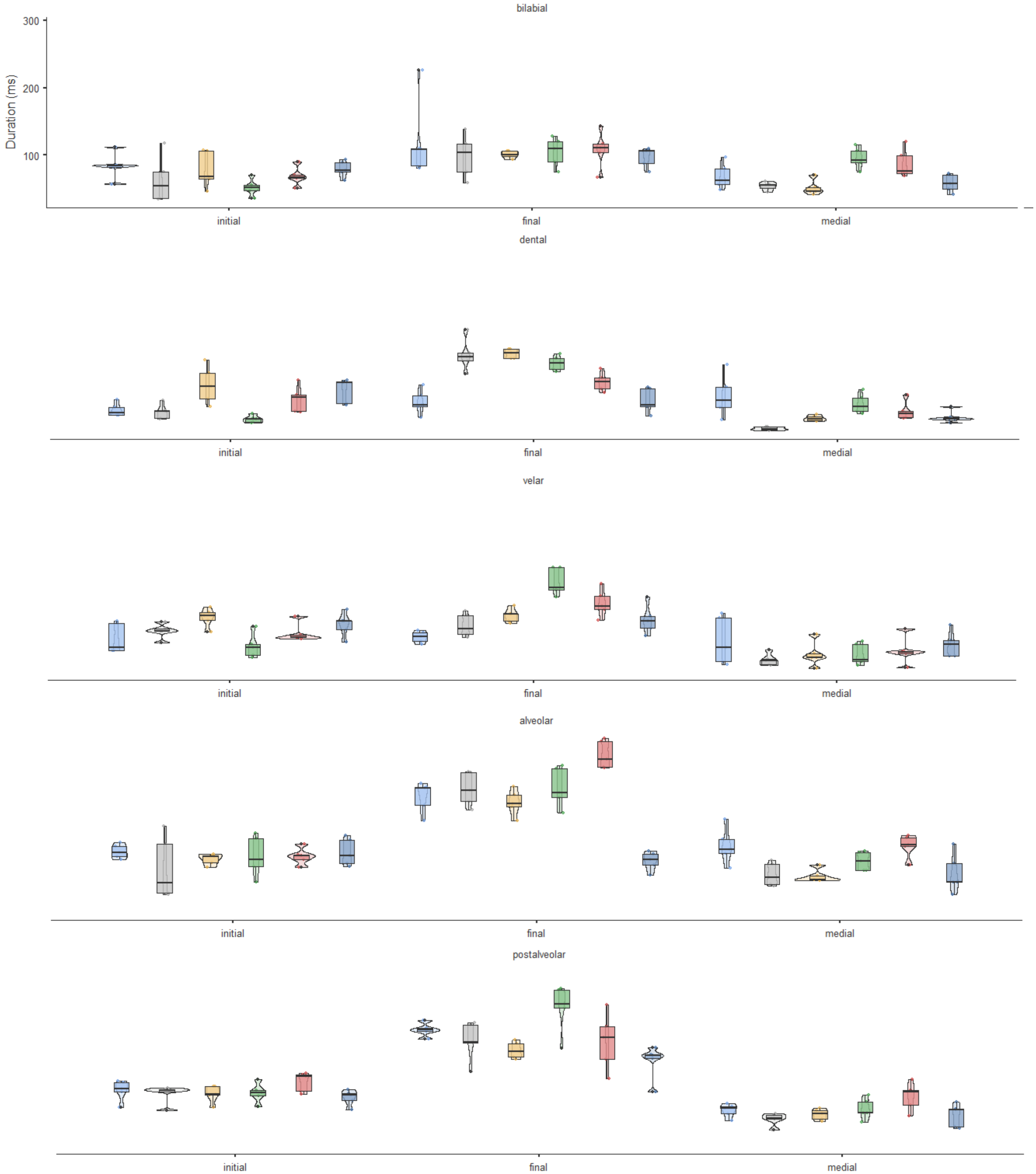

Figure 3: Speaker-by-speaker violin box plots of voiceless VOT means with quartile bars (broken up into five parts horizontally).

All voiced plosives and affricates had pre-voicing (negative VOT, example in Figure 4 below), though in Table 2, since we merged both voicing categories, we kept all values positive as to yield meaningful results (Tables 3 and onward all have clear positive vs. negative distinctions) – this table shows us VOT *duration* (not measurement per se), so pre-voicing or aspiration in itself has no bearing on duration. As we can see from this voicing-merged table, for stops, the means cluster very closely to one another for bilabials, dentals, and velars for word-initial positions, whereas affricates (either alveolar or post-alveolar) have significantly longer VOT. Word-finally, the situation is somewhat similar – the two affricate categories cluster far more closely to each other than for the plosives, as expected, though the tendency is less strong word-medially. In fact, the mean, standard error mean, and median are more clustered word-medially than for other positions.

Place of articulation	Voicing	mean (ms)	Std. error mean	median (ms)	mode (ms)	Range (ms)	Min. (ms)	Max. (ms)	Std. deviation	Skewness
bilabial	voiced	-93.2	**9.45**	-97.1	-41.0	**203**	**-16.5**	-219	**51.8**	0.286
	voiceless	71.1	4.12	69.5	84.6	82.7	35.2	118	22.6	0.326
dental	voiced	-89.0	8.26	-95.2	-31.0	161	-16.9	-178	45.2	0.00958
	voiceless	76.2	4.40	69.4	57.8	93.6	46.1	140	24.1	0.934
velar	voiced	-69.4	7.69	-59.9	-32.1	127	-24.2	-151	42.1	0.421
	voiceless	93.6	3.78	94.6	110	75.8	55.0	131	20.7	-0.104
alveolar	voiced	**-138**	7.96	**-143**	-61.0	175	-61.0	**-236**	43.6	0.0441
	voiceless	115	4.45	117	59.7	102	59.7	161	24.4	-0.506
postalveolar	voiced	**-115**	8.34	-116	-49.4	176	-49.4	-225	45.7	0.555
	voiceless	114	2.68	115	**122**	55.0	86.9	142	14.7	-0.189

Table 3 – Word-initial measurements and relevant descriptive statistics by place of articulation and voicing.

For word-initial *measurements* specifically, as seen in Table 3, we have results that match the tendency we see in English, Dutch, and German (Stoehr et al. 2017), insofar as VOT increases when we move from front to back in the oral cavity – voiceless bilabials here had a mean of 71.1 ms, voiceless dentals 76.2 ms, and voiceless velars had 93.6 ms, though for affricates, both alveolar and post-alveolar, which is anterior to the former, have essentially equal VOTs, at 115 ms and 114 ms respectively. Initial *k-* (93.6 ms SD 20.7 ms) in line with previous English experiments. The range was very large for voiced bilabials, as participants appeared to have large word-by-word variance –

sometimes back-to-back – this is reflected in the 51.8 ms standard deviation measurement. The skewness range is also somewhat large, but this is to be expected. Phonologically voiced plosives in word-initial position in WA thus appear to have very long pre-voicing at -70.2 ms for bilabials, -88 ms for dentals, and -86.1 ms for velars, and this time, velar voices plosives have shorter negative VOTs than either dental or bilabial ones.

Place of articulation	Voicing	mean (ms)	Std. error mean	median (ms)	mode (ms)	Range (ms)	Min. (ms)	Max. (ms)	Std. deviation	Skewness
bilabial	voiced	-70.2	6.35	-70.7	-97.5	119	**-15.8**	-135	34.8	0.345
	voiceless	105	5.52	106	106	167	58.9	226	30.2	2.15
dental	voiced	-88.0	5.66	-87.0	-66.2	148	-21.4	-170	31.0	0.417
	voiceless	116	6.18	121	**141**	130	54.0	184	33.8	-0.183
velar	voiced	-86.1	6.22	-91.1	-71.6	143	-17.7	-161	34.1	-0.374
	voiceless	120	5.63	117	120	114	75.5	190	30.9	0.681
alveolar	voiced	-140	**11.8**	-137	-23.3	**227**	-23.3	-251	**64.7**	-0.292
	voiceless	**202**	9.50	**209**	89.2	202	89.2	**292**	52.0	-0.571
postalveolar	voiced	-138	10.1	-140	-44.7	219	-28.9	-248	55.5	-0.0876
	voiceless	193	6.64	190	114	154	114	268	36.3	0.177

Table 4 – Word-final measurements and relevant descriptive statistics by place of articulation and voicing.

For word-final measurements, we see in Table 4 above that, once again, positive VOTs for voiceless plosives increase as oral anteriority increases – at 105 ms, 116 ms, and 120 ms for /p/, /t/, and /k/, respectively. Standard error means do not stray far from what we saw for word-initial results. The distinctions between the affricates are not noteworthy here, though one can immediately notice that WA maintains high positive VOTs for word-final affricates, as previous research such as Hacopian (2003) indicated for EA, and one can also notice that large range – 227 ms for voiced alveolars, 202 ms for voiceless alveolars, 219 ms for voiced post-alveolars, and 154 ms for voiceless post-alveolars. This theme of large inter-speaker variation will be revisited below.

Place of articulation	Voicing	mean (ms)	Std. error mean	median (ms)	mode (ms)	Range (ms)	Min. (ms)	Max. (ms)	Std. deviation	Skewness
bilabial	voiced	-59.6	3.17	-62.5	-50.7	73.6	**-16.8**	-90.4	17.4	-0.419
	voiceless	69.3	4.04	65.6	46.6	78.5	41.2	120	22.1	0.786
dental	voiced	-52.2	3.20	-51.6	-42.5	89.6	-22.4	-112	17.5	1.19
	voiceless	61.7	3.90	54.9	40.3	97.2	35.2	132	21.4	1.49
velar	voiced	-47.6	2.81	-48.0	-53.9	67.0	-19.6	-86.7	15.4	0.375
	voiceless	65.3	3.97	59.5	55.5	81.7	39.4	121	21.7	1.11
alveolar	voiced	-80.3	4.01	-76.5	-72.7	89.5	-45.6	-135	22.0	0.795
	voiceless	**107**	**4.88**	**105**	78.8	**111**	60.1	**171**	**26.7**	0.390
postalveolar	voiced	-67.2	3.11	-65.4	-67.6	71.5	-31.0	-103	17.0	0.165
	voiceless	86.0	3.12	83.3	**83.3**	75.1	57.9	133	17.1	0.763

Table 5 – Word-medial measurements and relevant descriptive statistics by place of articulation and voicing.

For word-medial measurements, we can readily notice that the ranges are much tighter than the results in our two previous tables (lowest-to-highest is 67-111 ms, compared to 55-203 ms for word-initial and 119-227 ms for word-final), as the smaller standard error means directly point to. Medial -*k*- has a VOT of 65.3 ms, generally more than English, especially in unstressed situations – the fact that WA is not a heavily stress-timed language may elucidate the reason for this gap. In terms of affricates, voiceless post-alveolar affricates VOTs are only 44.56% of what they are in word-final position, and their voiced counterparts 48.55%. This is similar to the findings in Hungarian (Pycha 2009).

The two EA bidialectal speakers (Speakers 1 and 6) are quite close to our four other WA speakers (Speakers 2, 3, 4, and 5) – for certain measurements (like the prevoicing difference for plosives), they cluster closer to each other than the four other WA native speakers as they have more prevoicing for voiced plosives, and they have less prevoicing for their affricates than the WA speakers. Some authors in the literature have pointed out that the three-way EA distinction is not solely based on VOT – some EA speakers use breathy voice for their phonologically voiced plosives and affricates (Seyfarth & Garellek 2018), whilst in a few EA dialects, some ejectivize their unaspirated phonologically voiceless plosives and affricates (Grawunder 2010). We did not detect any attempt at a non-modal type of phonation in our two bidialectal speakers. When we compare Speaker 1 and 6 as seen in the model coefficients table below (Table 6) by running a multinomial logistic regression, we can see that they are similar in many respects, given their rather high p-values and standard errors (SE). Though we cannot read into this too much because the sample is too small, it is nevertheless an interesting finding.

Model Coefficients

Speaker	Predictor	Estimate	SE	Z	p
Speaker6 - Speaker1	Intercep	1.14492	0.59505	1.9241	0.054
	Duration (ms)	-0.01698	0.00600	-2.8291	0.005
	Position:				
	final – initial	0.79745	0.49336	1.6164	0.106
	medial – initial	-0.28319	0.41496	-0.6825	0.495
	Place:				
	dental – bilabial	0.05033	0.52080	0.0966	0.923
	velar – bilabial	0.19783	0.52509	0.3768	0.706
	alveolar – bilabial	0.94343	0.61927	1.5235	0.128
	postalveolar – bilabial	0.82482	0.59634	1.3831	0.167

Table 6 - Applying a multinomial logistic regression comparing Speakers 1 and 6.

We have already noted the relatively large individual variations (both inter- and intra-speaker). Heritage language research has shown that bilingual and trilingual heritage L1 speakers tend have somewhat large inter-speaker variation, both in terms of syntax-semantics (Cagnola et al. 2019) and phonetics-phonology (Nagy & Brook 2020). It may also be partly due to the strange circumstances of the recordings – that of speaking into a microphone, remotely, alone in a room, that is causing some of our speakers to speak at an uneven pace. We also noticed that some of the less-familiar words were pronounced more slowly (given that their reaction times to recognize the words were much longer) – this may be a speech hesitancy effect which increases VOT.

And if we ask ourselves – which factors (and which combination of factors) have a statistically significant effect on VOT duration? The answer is – all of them, according to our analysis of variance tools in Table 7. The omega-squared (ω^2) value, which, like eta-squared, is a measure of effect size (viz. measure of association), widely viewed as a lesser biased alternative to eta-squared, especially when sample sizes are somewhat small like they are in this experiment, shows us that the speaker-to-speaker effect is indeed somewhat large, and so is the effect of position and place of articulation.

ANOVA - Duration (ms)								
	Sum of Squares	**df**	**Mean Square**	**F**	**p**	**η²**	**η²p**	**ω²**
Overall model	940070	89	10563	25.00	< .001			
Position	396834	2	198417	469.66	< .001	0.363	0.723	0.362
Place	280406	4	70101	165.93	< .001	0.257	0.648	0.255
Speaker	25461	5	5092	12.05	< .001	0.023	0.143	0.021
Position ✻ Place	72822	8	9103	21.55	< .001	0.067	0.324	0.064
Position ✻ Speaker	61330	10	6133	14.52	< .001	0.056	0.287	0.052
Place ✻ Speaker	37048	20	1852	4.38	< .001	0.034	0.196	0.026
Position ✻ Place ✻ Speaker	66171	40	1654	3.92	< .001	0.061	0.303	0.045
Residuals	152089	360	422					

Table 7 – Analysis of variance (ANOVA) examination of all factors

V – Discussion and Conclusion

As can be seen from our various statistical analyses, a number of factors affect VOT duration – namely, the position of the plosive or affricate within a word (with word-medial VOTs being the least distinguishable among themselves vis-à-vis place of articulation) and place of articulation each play a large role.

Our results suggest that English is likely affecting the WA VOT system, but asymmetrically. For aspirated voiceless plosives and aspirated voiceless affricates, our results are more English-like, whereas for voiced plosives and voiced affricates, our results are more French-like, which is unexpected because there would have been more than enough of a salient difference between our highly positive VOTs for voiceless sounds versus hypothetically near-zero or barely positive VOTs for phonologically voiced sounds. Therefore, overall, our hypothesis is only partly supported by the experiment's results.

As predicted by our language contact hypothesis, our results partly run against Kelly & Keshishian (2019)'s findings – in their case for Arabic-dominant WA speakers, the VOT values aligned better with unaspirated EA stops (between 10-30 ms mostly, with a few outliers going above 50 ms) than with EA aspirated stops (typically 100-150 ms) – in our case, likely due to English influence, our voiceless aspirated stops and affricates have typical EA values (that is to say, VOT values at least equal if not higher than those typically seen in English). But unlike English, these high VOTs are not greatly diminished in word-medial and word-final positions, likely due to the minimal effect stress has on syllabic prominence in WA.

In our experiment, word position had a statistically significant effect everywhere, for each category of sound, unlike in Kelly & Keshishian (2019) – in their statistical results, they report that word position (note that they only compared initial and medial positions) yielded a *t*-score of 0.023 and a *p*-value of 0.98, whereas we have a *p*-value of <0.001.

We then have the issue of pre-voicing – our results are nearly identical to those of Kelly & Keshishian (2019) – the phonological voiced sounds are patterning with typical French speakers – but the issue that comes to the fore is why our results are not closer to the English norm. We do not have a good explanation for this, other than suggesting a secondary language contact influence from Québec French – which has highly prevoiced phonologically voiced stops and affricates. As a way of illustration, here is a clear example of a very strongly prevoiced word-initial [b] in Speaker 4 (the speaker with the most French influence under the age of 5 – compare him with the others in Figure 2):

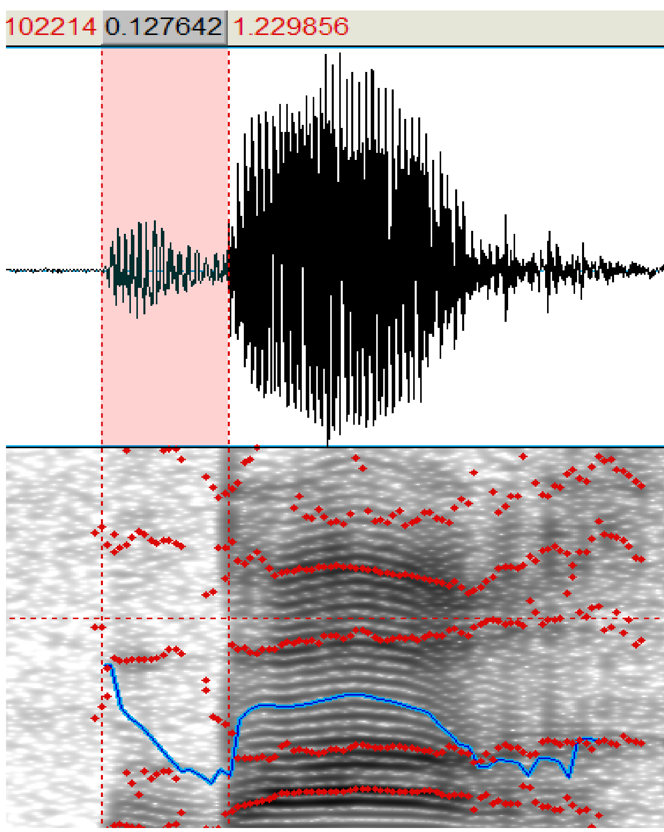

Figure 4 – Example of strong pre-voicing at 127 ms; Speaker 4, word-initial [b] in [bɑʁ] ‘cold’.

Another point worth noting is that WA does not have unreleased syllable- or word-final stops - English speakers very often have unreleased syllable-final stops, such as *logged on* [ˌlɒɡ̚dˈɒn] or a little more rarely in utterance-final position, *gap* [ɡæp̚]. This is clearly not true for WA word-final plosives and affricates, as, for example, Speaker 1 produced [ɑpʰ] 'palm' with a VOT of 226 ms, and [ɑɡɑnt͡ʃʰ] 'ear' with a VOT of 234 ms, and although most other participants were not as high for these particular words, they still exhibited clear aspiration with a significant delay and eventual burst (the means for combined final plosives and affricates for all speakers is 113.7 ms and 197.5 ms, respectively).

But the conclusion we pull from our data agrees with Kelly & Keshishian (2019)'s suggestion that their data may be skewed by the Arabic language dominance of their WA speakers, the same way our data is likely being influenced by the dominance of our speakers' English language in their linguistic repertoire. A larger theoretical point here is that since we have data from Arabic-dominant WA speakers, our comparative analysis of the VOT behavior exhibited by our speakers here indicates that there is unlikely to be a single across-the-board principle that governs the influence of a dominant language on a minority language.

For further research, other forces such as articulatory factors, universal tendencies, normal diachronic change in each of the languages studied, and sociolinguistic pressures, must be considered. And such factors must be carefully considered when studying heritage languages, as sociolinguistic and psychosocial factors may have a stronger influence than for non-heritage languages. Another potential point of research here is to see if the influence of English (and French) was stronger for those exposed to English earlier than for those who were exposed later – our small sample size was too homogeneous in this respect for us to have been able to appreciably subdivide our data.

VI – References

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Appendix

Plosive word list

		Voiced	Voiceless Aspirated
Initial	Bilabial	**պա___** պաղ /bɑʁ/ 'cold' պարզ /bɑɾz/ 'simple' պաշտել /bɑʃdel/ 'to worship' պարկ /bɑɾg/ 'bag' պաչիկ /bɑt͡ʃʰig/ 'kiss'	**բ/փա___** փայտ /pʰɑjd/ 'wood' փառ /pʰɑr/ 'whitish film, pellicle' փախչիլ /pʰɑxt͡ʃʰil/ 'to escape' բառ /pʰɑr/ 'word' բան /pʰɑn/ 'thing'
	Dental	**տա___** տառ /dɑr/ 'letter' տաս /dɑs/ 'ten' տափակ /dɑpʰɑg/ 'flat' տակ /dɑg/ 'under' տալ /dɑl/ 'to give'	**դ/թա___** թառ /tʰɑrə/ 'perch' թաս /tʰɑsə/ 'cup' թափ /tʰɑpʰ/ 'power, wave' դառ /tʰɑr/ 'pungent' դաս /tʰɑs/ 'lesson'
	Velar	**կա___** կարի /gɑɾi/ 'very much' կարս /gɑɾs/ 'Kars (city)' կացին /gɑt͡sʰin/ 'axe' կաթ /gɑtʰ/ 'milk' կախել /gɑxel/ 'to hang'	**գ/քա___** քար /kʰɑɾ/ 'stone' քան /kʰɑn/ 'than' քայլ /kʰɑjl/ 'step' գառ /kʰɑr/ 'lamb' գահ /kʰɑh/ 'throne'
Final	Bilabial	**___ապ** շտապ /əʃdɑb/ 'urgent' կապ /gɑb/ 'knot' տապ /dɑb/ 'sultry' խուճապ /xud͡ʒɑb/ 'panic' պարապ /bɑɾɑb/ 'empty'	**___աբ/փ** կափ /gɑpʰ/ 'knocker' տափ /dɑpʰ/ 'plain' ափ /ɑpʰ/ 'palm' արաբ /ɑɾɑpʰ/ 'Arab' սարսափ /sɑɾsɑpʰ/ 'horror'
	Dental	**____ատ** աղատ /ɑʁɑd/ 'supplication' ազատ /ɑzɑd/ 'free' պատ /bɑd/ 'wall' դատ /tʰɑd/ 'trial' զատ /zɑd/ 'apart'	**____ադ/թ** շաբաթ /ʃɑpʰɑtʰ/ 'week' գագաթ /kʰɑkʰɑtʰ/ 'peak' կաթ /gɑtʰ/ 'milk' բադ /pʰɑtʰ/ 'duck' խալաթ /xɑlɑtʰ/ 'bathrobe'

	Velar	**___ակ** թակ /tʰɑg/ 'mallet' սակ /sɑg/ 'price' բակ /pʰɑg/ 'yard, court' էակ /eɑg/ 'being, living creature' առակ /ɑrɑg/ 'fable'	**___ագ/ք** թաք /tʰɑkʰ/ 'odd' բաք /pʰɑkʰ/ 'vessel' հավաք /hɑvɑkʰ/ 'gathering' թագ /tʰɑkʰ/ 'crown' սագ /sɑkʰ/ 'goose'
Medial	Bilabial	**___պա___** ապա /ɑbɑ/ 'then' ապակի /ɑbɑgi/ **'**glass**'** գրպան /kʰəɾbɑn/ 'pocket' սպաս /əsbɑs/ 'service, alley' կապար /gɑbɑɾ/ 'bullet, lead'	**___բ/փա___** գաղափար /kʰɑʁɑpʰɑɾ/ 'idea' թլփատել /tʰəlpʰɑdel/ 'to circumcise' չափանիշ /t͡ʃʰɑpʰɑniʃ/ 'criterion' ագահաբար /ɑkʰɑhɑpʰɑɾ/ 'greedily' ամբար /ɑmpʰɑɾ/ 'barn'
	Dental	**___տա___** ազատագրել /ɑzɑdɑkɾel/ 'liberate' անհատակ /ɑnhɑdɑg/ 'bottomless' գտանք /kʰədɑnkʰ/ 'we found' ատամ /ɑdɑm/ 'tooth' վստահ /vəsdɑh/ 'certain'	**___դ/թա___** մշակութային /mʃɑgujtʰɑyin/ 'cultural' օրթախ /oɾtʰɑx/ 'partner, associate' քաթար /kʰɑtʰɑɾ/ 'Qatar' անդամ /ɑntʰɑm/ 'member' արդար /ɑɾtʰɑɾ/ 'fair, just'
	Velar	**___կա___** անկախ /ɑngɑx/ 'independent' առարկայ /ɑrɑɾgɑ(j)/ 'object' բնական /pʰənɑgɑn/ 'natural' ականջ /ɑgɑnt͡ʃʰ/ 'ear' ճակատ /d͡ʒɑgɑd/ 'front, forehead'	**___գ/քա___** աղքատ /ɑʁkʰɑd/ 'poor' արքայ /ɑɾkʰɑ(j)/ 'king' հանքաբան /hɑnkʰɑpʰɑn/ 'minerologist' զգալ /əzkʰɑl/ 'feel' հագած /hɑkʰɑd͡z/ 'dressed'

Affricate word list

		Voiced	**Voiceless Aspirated**
Initial	Alveolar	**ծա___** ծակ /d͡zɑg/ 'hole' ծամ /d͡zɑm/ 'hair, braid, plait' ծառ /d͡zɑr/ 'tree' ծայր /d͡zɑjɾ/ 'edge, tip' ծալք /d͡zɑlkʰ/ 'fold'	**ձ/ցա___** ցաւ /t͡sʰɑv/ 'pain' ցանց /t͡sʰɑnt͡sʰ/ 'net, network' ցամաք /t͡sʰɑmɑkʰ/ 'dry, lifeless' ձագ /t͡sʰɑkʰ/ 'pup' ցանկապատ /t͡sʰɑngɑbɑd/ 'fence'

	Post-alveolar	**ճա___** ճաղ /d͡ʒɑʁ/ 'rod, spoke' ճան /d͡ʒɑn/ 'ankle' ճաք /d͡ʒɑkʰ/ crack' ճարպ /d͡ʒɑɾb/ 'fat, tallow' ճանկ /d͡ʒɑng/ 'claw'	**չ/ջա___** չար /t͡ʃʰɑɾ/ 'bad, evil' չափ /t͡ʃʰɑpʰ/ 'size' ջանք /t͡ʃʰɑnkʰ/ 'effort, drive' ջարդ /t͡ʃʰɑɾtʰ/ 'massacre' ջանասեր /t͡ʃʰɑnɑseɾ/ 'industrious'
Final	Alveolar	**___ած** ցած /t͡sʰɑd͡z/ 'low' առած /ɑɾɑd͡z/ 'proverb, adage' խմած /xəmɑd͡z/ 'intoxicated' հագած /hɑkʰɑd͡z/ 'dressed' մեռած /meɾɑd͡z/ 'dead'	**___աձ/ց** բաց /pʰɑt͡sʰ/ 'open' ցանց /t͡sʰɑnt͡sʰ/ 'net, network' թաց /tʰɑt͡sʰ/ 'wet' հաց /hɑt͡sʰ/ 'bread' գնաց /kʰənɑt͡sʰ/ 'he/she went'
	Post-alveolar	**____աճ** տհաճ /dəhɑd͡ʒ/ 'unpleasant' պատշաճ /badʃɑd͡ʒ/ 'appropriate, decent' բարգավաճ /pʰɑɾkʰɑvɑd͡ʒ/ 'prosperous' հաճ /hɑd͡ʒ/ 'happy' աճ /ɑd͡ʒ/ 'increase, growth'	**____աչ/ջ** խաչ /xɑt͡ʃʰ/ 'cross' պաչ /bɑt͡ʃʰ/ 'kiss' կանաչ /gɑnɑt͡ʃʰ/ 'green' քաջ /kʰɑt͡ʃʰ/ 'brave' առաջ /ɑɾɑt͡ʃʰ/ 'before'
Medial	Alveolar	**___ծա___** լծակ /ləd͡zɑg/ 'lever' արծաթ /ɑɾd͡zɑtʰ/ 'silver' ածական /ɑd͡zɑgɑn/ 'adjective' պայծառ /bɑjd͡zɑɾ/ 'brilliant' քթածակ /kʰətʰɑd͡zɑg/ 'nostril'	**___ձ/ցա___** արձան /ɑɾt͡sʰɑn/ 'statue' անձամբ /ɑnt͡sʰɑmpʰ/ 'personally' դերձակ /tʰeɾt͡sʰɑg/ 'tailor' անցած /ɑnt͡sʰɑd͡zʰ/ 'gone' հրացան /həɾɑt͡sʰɑn/ 'rifle'
	Post-alveolar	**___ճա___** աճառ /ɑd͡ʒɑɾ/ 'cartilage' վճար /vəd͡ʒɑɾ/ 'fee' օճառ /od͡ʒɑɾ/ 'soap' կոճակ /god͡ʒɑg/ 'button' դավաճան /tʰɑvɑd͡ʒɑn/ 'chess'	**___չ/ջա___** հաչաղ /hɑt͡ʃʰɑʁ/ 'envy, rancour' աղաչանք /ɑʁɑt͡ʃʰɑnkʰ/ 'entreaty, request' փչացնել /pʰət͡ʃʰɑt͡sʰənel/ 'to spoil, to mar' միջատ /mit͡ʃʰɑd/ 'insect, bug' անջատել /ɑnt͡ʃʰɑdel/ 'to disconnect, turn off'