AN ACOUSTIC STUDY OF FRICATIVES IN TEMIRGOY ADYGHE

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ABSTRACT

This paper presents an acoustic study of voiceless fricatives in the Temirgoy dialect of the Adyghe language (North West Caucasian, Circassian). The Circassian languages are well-known for their large consonant inventories. Using data gathered on a field trip to the Caucasus, the analysis focusses on three acoustic properties: centre of gravity, standard deviation and general slope pattern. Results show that while most fricative pairs can be reliably distinguished via centre of gravity alone, the spectral characteristics of some pairs (most notably /ʃ, ʃʲ/, /ŝʷ, χʷ/ and /ħ, χ(ʷ)/) are highly similar. For the typologically rare closed postalveolar fricatives /ŝ, ŝʷ/, both centre of gravity and standard deviation were found to be decisive acoustic cues.

Keywords: fricatives, acoustic phonetics, North West Caucasian languages, Adyghe.

1. INTRODUCTION

This paper investigates the acoustic properties of eleven voiceless fricatives in Adyghe, a North-West Caucasian (NWC) language spoken mainly in Russia and Turkey. The native dialect of the seven speakers whose recordings were analysed was Temirgoy, a variety very similar to literary Adyghe. The fricatives under investigation are: /f, s, ŝ, ŝʷ, ʃ, ʃʲ, ɬ, x, χ, χʷ, ħ/.

Descriptions of the size of the literary Adyghe consonant inventory (which is equal to that of Temirgoy Adyghe) range from 49-55 [18], 54-55 [8] and 55 [12, 11, 10] to 56 [4] phonemes. The typologically large number is primarily due to i) distinctiveness of 11 poas, ii) a three-way contrast in phonation, iii) distinctive secondary articulations. Among the most notable sounds is the closed postalveolar fricative /ŝ/ along with its ejective /ŝ'/ and labialised /ŝʷ, ŝ'ʷ/ counterparts.

Previous research on the phonetics of NWC languages includes data discussed in [6, 8, 7, 2, 3], though a detailed description of the acoustic properties of Temirgoy voiceless fricatives has not been conducted as of yet.

The paper is structured as follows: section 2 outlines the methodology employed for gathering and the analysis of the voiceless fricatives. Section 3 presents the quantitative results, including statistic comparison. Section 4 discusses the acoustic properties of some selected sounds in greater detail.

2. METHODOLOGY

The data analysed in this study were recorded in July and August 2010 during a field trip to the villages of Chatažukaj (a. Хатажукай) and Pšičo (a. Пшичо), situated alongside the river Fars (Фарс) in the Republic of Adygea in Russia, about 30 miles south of Maykop.

Seven female native speakers of Temirgoy Adyghe (aged 19 to 59) were recorded in a classroom at the local school with the windows shut. The speakers produced three repetitions of a set of 11 words containing the target voiceless fricative in the onset of the first syllable directly followed by /a/. The words were embedded in a carrier phrase: /gʷəʃʲəʔew (word) dʒʲərjə ʃʲe qeʔʷeʒʲ/ 'Say (word) three more times'. Speakers were recorded using a hama EL-80 headset with an omnidirectional microphone plugged into an Olympus LS-10 Linear PCM Recorder. The recording settings were set to .wav, 44.1 kHz, 16-bit, stereo.

The audio files were segmented and analysed using Praat [5]. For each sound, a 25 msec spectral slice was created in the middle portion of the sound. For each slice, center of gravity (cog) was extracted by using 'Get centre of gravity... (Power = 2.0)'. The 25 msec segments were then saved into separate files. In addition, standard deviation (std) was extracted from spectrum objects obtained from those files using 'Sound: To Spectrum...' ('Fast' was disabled) and 'Get standard deviation... (Power = 2.0)'. Finally, Ltas objects (Bandwidth = 100) were created for all segments and merged into Ltas averaged spectra of the eleven individual sounds. Pairwise two-sample t-tests (BH p-adjustment) were run for cog and std on all sounds. Significance levels used here are *not significant* ($p > 0.05$), *marginally significant* ($p < 0.1$), *significant* ($p < 0.05$), *strongly significant* ($p < 0.01$) and *highly significant* ($p < 0.001$).

3. QUANTITATIVE ANALYSIS

Tables 1 to 4 provide an overview of cog and std values for the eleven fricatives as produced by each speaker. One-way ANOVA yielded a highly significant dependence of cog on sound as well as a highly significant dependence of std on sound. No dependencies were found for cog/speaker (p = 0.534) and std/speaker (p = 0.386).

	/f/	/s/	/ŝ/	/ŝʷ/	/ʃ/	/ʃʲ/
F_01	8447	7048	6545	4048	5056	5123
F_02	7232	8134	6157	3430	4820	5310
F_03	6332	8153	5252	2942	3708	4261
F_04	6185	8374	5443	3669	4463	4550
F_05	6016	8411	6626	3915	4654	5601
F_06	6939	8378	5792	4220	4653	3603
F_07	8133	7709	5645	3223	5325	5549
mean	7041	8030	5923	3640	4668	4857
std	887	460	495	434	474	690

Table 1: cog measures for sibilants and /f/.

	/ɬ/	/x/	/χ/	/χʷ/	/ħ/
F_01	5021	2301	n/a	n/a	2886
F_02	6760	2396	n/a	n/a	2636
F_03	6072	2039	2644	2346	2175
F_04	5316	1420	2672	1885	2772
F_05	6015	1814	3170	2072	1938
F_06	5951	2590	2866	2218	2345
F_07	5725	1941	2774	4275	2704
mean	5837	2072	3059	2559	2494
std	521	366	190	871	323

Table 2: cog measures for non-sibilants.

	/f/	/s/	/ŝ/	/ŝʷ/	/ʃ/	/ʃʲ/
F_01	3242	2655	1204	2245	1784	1427
F_02	2576	2718	1646	2159	2185	2154
F_03	2990	1921	1576	1863	2330	1786
F_04	4056	2123	1552	2328	1881	1602
F_05	2014	1707	1632	2698	1550	1605
F_06	1978	1795	1217	2597	2108	1594
F_07	2920	1771	1621	804	1401	503
mean	2825	2099	1492	2099	1891	1524
std	672	392	181	587	315	468

Table 3: std measures for sibilants and /f/.

The following observations could be made for *centre of gravity* (cf. fig. 1 and 2):

- cog was found to be a strong predictor for distinguishing fricative pairs: 81.8% (45/55) of all fricative pairs showed at least a significant difference with respect to cog and 85.5% (47/55) were at least marginally different
- Values for cog increase as poas move forward: posterior fricatives have lower values than sibilants and the anterior non-sibilants /f, ɬ/
- /s/ had the highest overall cog value; the difference was significant for all other fricatives except /f/

	/ɬ/	/x/	/χ/	/χʷ/	/ħ/
F_01	2678	1950	3378	3903	1678
F_02	2205	2044	3950	4617	2280
F_03	2413	1472	2851	3161	2004
F_04	2989	1244	3412	3408	1573
F_05	2896	1716	3559	4077	1550
F_06	2566	3210	3901	3608	2161
F_07	2940	2731	2589	3510	2269
mean	2670	2053	3377	3755	1931
std	272	646	468	451	300

Table 4: std measures for non-sibilants.

- Among the posterior sounds, cog difference was significant only for /x, χ/
- cog was unable to distinguish between the two labialised sounds /ŝʷ, χʷ/ and also between the two postalveolars /ʃ, ʃʲ/

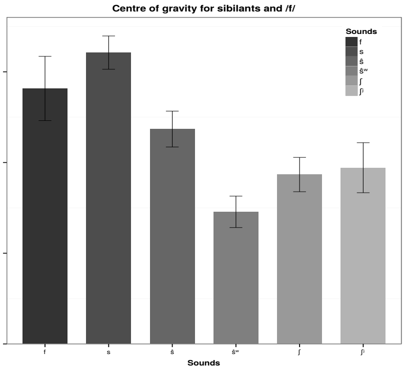

Figure 1: cog barplots for /f/ and sibilants.

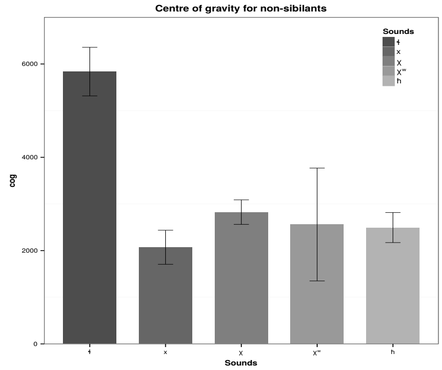

Figure 2: cog barplots for /ɬ/ and posteriors.

The following observations could be made for *standard deviation* (cf. fig. 3 and 4):

- std was lowest for /ŝ/ and highest for /χʷ/
- /χ/ and /χʷ/ had the highest number of significantly different partners
- std of /x/ was significantly different only from the uvulars
- Labialised /χʷ, ŝʷ/ had a higher std than their plain counterparts, whereas palatalised /ʃʲ/ had a lower std than plain /ʃ/

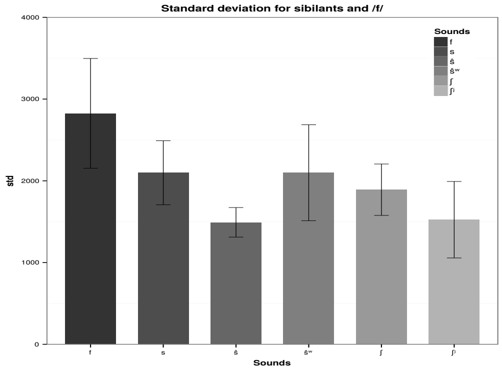

Figure 3: std barplots for /f/ and sibilants.

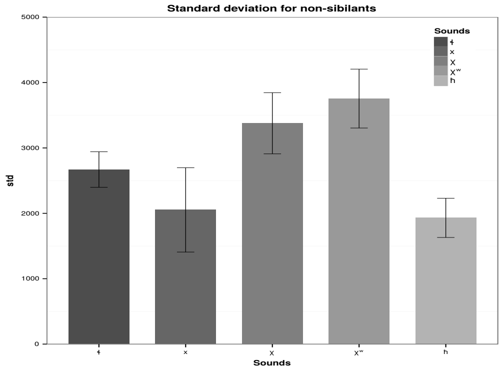

Figure 4: std barplots for /ɬ/ and posteriors.

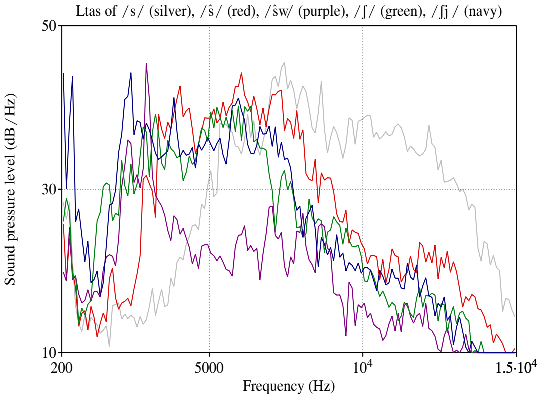

Figure 5: Averaged Ltas for sibilants.

4. DISCUSSION

4.1. Sibilants

The apical dental-alveolar /s/ has the highest cog and the second highest std. The spectral slope is campanulate, with a global maximum at 7.5 kHz, a moderate fall until 12 kHz and a steep fall thereafter. The high cog is conditioned by the short distance between the constriction and the obstacle (the upper incisors). For some speakers (e.g. F_07), energy is concentrated in even higher regions around 10 kHz in the last half or third of [s] which can be attributed to strong secondary turbulences emerging from the small oral cavity in front of the constriction; in such cases, a section from the first part of the sound was taken for measurements. A high cog average for /s/ is common cross-linguistically [1, 17] (but cf. [9] in which cogs of /s/ center around 4-5 kHz and are thus barely higher than those of /ʃ/).

/ŝ/ is best described as a *closed postalveolar* voiceless fricative, although a number of competing labels such as *alveolopalatal* have been put forward as well [14, 15, 3]. /ŝ/ is produced by positioning the tip of the tongue behind the lower incisors and forming a constriction in the postalveolar region. The tongue body is almost flat and stretches both in the front and back direction, thus causing pressure of the postdorsum towards the posterior pharyngeal wall [11]. The acoustic measurements revealed that /ŝ/ has the second highest cog among sibilants, the average value being only slightly higher than that of /ɬ/. The overall spectral line of /ŝ/ is characterised by noise distributed in a vast frequency region (ca. 3.5–7.5 kHz) with a global maximum at 6 kHz. It resembles that of /s/ shifted to the left, which corresponds to the constriction formed deeper in the oral tract. /ŝ/ has the lowest std of all sounds, which is due to the tripartite structure of its spectrum that is divided into an area of low energy preceding a 4 kHz-band of noise after which the curve declines steeply. The stiffness of the tongue body is the main articulatory correlate of the low std value.

/ŝʷ/ has a global maximum at 2750 Hz followed by a steep fall that is interrupted at the beginning of a local area of higher energy from appr. 6-8 kHz. Among the sibilants, /ŝʷ/ has a high std (not significantly different from /s/ and /ʃ/) and the lowest cog.

The spectral curves of both /ʃ/ and /ʃʲ/ display a high-energy region from 2.5 kHz up to 6-7 kHz, which goes well in line with cross-linguistic observations [9]. std is significantly ($p < 0.05$) higher for /ʃ/ than for /ʃʲ/. /ʃ/ and /ʃʲ/ are very close perceptually and do not particularly differ with respect to formant transitions. A similar picture has been reported for other speakers of the Temirgoy and Shapsugh dialects [3]. A low phonetic distinctiveness between plain and palatalised non-anterior sibilants could well have contributed to the loss of this distinction in Kabardian, the other member of the Circassian family.

cog order among sibilants (/s/ ≫ /ŝ/ ≫ /ʃ, ʃʲ/ ≫ /ŝʷ/) is compatible with articulatory models that integrate frontness/backness of constriction as well as the down-levelling effects of both secondary labialisation and a large sublingual cavity.

4.2. Posteriors

/x/ has the lowest cog value. The spectrum is characterised by an early peak (which is also the global maximum) at 1250 Hz, followed by a low-amplitude phase with a local minimum at 3.5 kHz. Secondary peaks are located at 4.5 kHz and 7 kHz. These data back arguments presented by Catford [7] to treat Adyghe /x/ as velar and not as palatal.

/χ/ has the highest cog among the posterior sounds and the overall second highest std. The spectrum is characterised by an early peak (which is also the global maximum) at 1250 Hz (similar to /x/) and a local minimum at 2750 Hz. The curve then continues relatively flat, but with higher energy than /x/. High std values are due to the hardly controllable and irregular nature of uvula movement, resulting in (low-energy) turbulences throughout almost the entire frequency range.

The spectral curve of /χʷ/ resembles that of /χ/ shifted to the left and with a lower overall intensity up to appr. 3 kHz. From 3 kHz onwards, the spectra of the uvulars are nearly indiscriminable. The high degree of inter-speaker variation in cog values is due to some variability in timing of the labial portion of /χʷ/. /χʷ/ has the highest overall std. The main acoustic cue for distinguishing low-cog and high-std /χ/ and /χʷ/ is the [w]-like transition to the adjacent vowel. Temirgoy Adyghe velar and uvular fricatives match cross-linguistic generalisations that characterise those sounds as having an acute spectral peak below 2 kHz and additional peaks in a region between 4 and 8 kHz [9].

/ħ/ has the lowest std among non-sibilants and the second lowest overall cog (after /x/). Its spectrum contains energy distributed in a 1-3 kHz bandwidth followed by a steady decline of energy in the higher frequency regions. This can be seen as evidence that the sound in question is indeed pharyngeal, as it lacks the several distinctive peaks resembling vowel formants typical of /h/ [13] and does not have its bulk of energy at the approximate locations of the formants of the adjacent vowel /a/, which would be typical of /ʜ/ [16, pp. 167f].

4.3. /f/, /ɬ/

/f/ has the second highest cog after /s/ and the third highest std after /χʷ/ and /χ/. The high std values can be attributed to the physiological properties of the articulators (imbalance between hardness of upper incisors and softness of lower lip).

A study of Turkish Kabardian fricatives found a high std for /f/, but also a strikingly lower cog (mean 4802 Hz) compared to my data [2]. While it is tempting to try and link the differences in cog to different diachronic provenience (f < *ŝʷ in Kabardian, f < *xʷ in Adyghe), a possible impact of recording quality as indicated by an extraordinarily low sound pressure level can unfortunately not be ruled out for the Kabardian data.

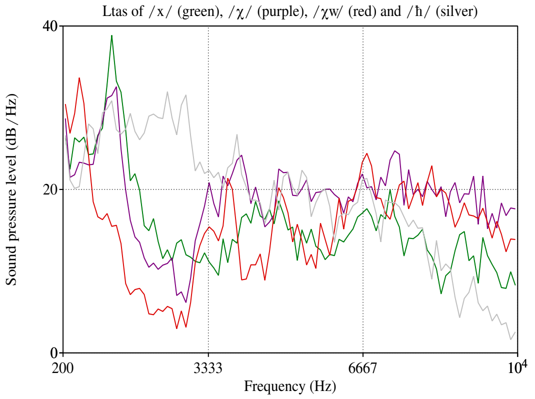

Figure 6: Averaged Ltas for posteriors.

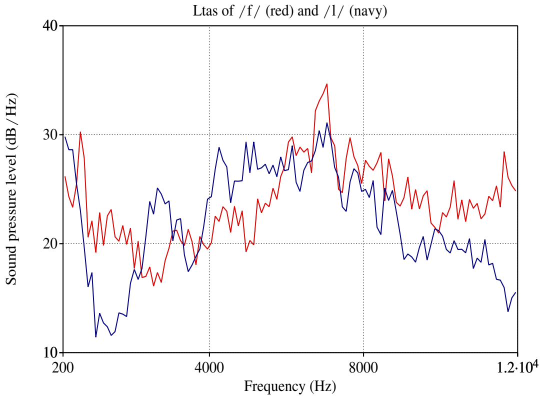

Figure 7: Averaged Ltas for /f/ and /ɬ/.

The spectrum of /ɬ/ is characterised by a local minimum at 2.5 kHz from which the curve slowly proceeds to the global maximum at 7 kHz. A mean cog of 5837 Hz is consistent with cross-linguistic observations, e.g. [16, p. 203] for Welsh. The only sound for which cog is not significantly different from /ɬ/ is /ŝ/ (not /ʃ/ as in Turkish Kabardian [2]).

5. CONCLUSION

In this study, eleven voiceless fricatives of Temirgoy Adyghe were analysed with respect to cog, std and general spectral properties. The study revealed an overall high rate of distinction provided by those parameters. Exceptions were mostly fricatives with secondary articulation for which other acoustic cues such as transitional properties are assumed to be relevant. Further research, especially on formant transitions, will be needed to complement the analysis presented here.

6. ACKNOWLEDGEMENTS

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