STRENGTH MATTERS?

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ABSTRACT

Linguistic decriptions refer to the 'strength of articulation' or 'articulatory force' of consonants. However, the status of this opposition is unclear. Minimally distinct phonological segments differ along many physical dimensions, which may all have some role in marking their identity. Hence, a theoretical basis for distinguishing essential and contingent differences is required. One principle proposed is 'subordination'. A difference in 'strength' between minimally different consonants is generally subordinated to a contrast of voicing or gemination. But some Dagestanian languages may provide the evidence that strength is not always a subordinate segmental property or a prosodic/pragmatic feature. Audio, aerodynamic and palatographic data on Bagwala and more limited audio and palatographic data on Dargi and Archi has been collected and examined. In the fricatives the phonetic realization of the 'strength' distinction includes variation of constriction degree while remaining within the limits of the critical range for friction; durational differences are small.

1. CONSONANT STRENGTH

Does consonant strength ever serve as the primary dimension of contrast in any language? It is not unusual to find phonetic or phonological descriptions which refer to the 'strength of articulation' or 'articulatory force' of consonants and describe contrasting categories as 'strong' and 'weak' or 'fortis' and 'lenis.' However, the status of this opposition is unclear. Ladefoged and Maddieson [8] concluded that there were no clear cases in which articulatory strength had been shown to be the principle distinguishing factor between classes of consonants.[1]

A number of possible measures of articulatory force or strength have been proposed, including direct measures of the pressure of articulatory contact [11] and of electrical activity in the muscles [12], and more indirect measures such a rate of articulator movement [13] or contact area on the palate [2, 3]. Articulatory strength differences have also been inferred from purely acoustic measures [10] but these are more ambiguous.

A difference in 'strength' between minimally different consonants in matching positions appears generally to be associated with a contrast of either voicing (e.g. Dutch, Swedish [12, 2]) or gemination (varieties of Berber [9, 10]). Measurable differences in strength also correlate with position in a utterance, speech rate, and emphasis and thus signal properties of discourse structure and prosody, rather than segment identity [3]. Since minimally distinct phonological segments differ along many physical dimensions, all of which may have some role in marking their identity, a theoretical basis for distinguishing those differences which play an essential role from those whole role is contingent is required.

1.1. Subordination

The implicit practice of many phoneticians and phonologists in distinguishing essential and contingent properties of contrasting segments seems to be to look for 'subordination'. Subordination has two aspects. Physical differences between segments on a given measure may be subordinate to other, more salient, uses of the given parameter even in the same segment type. And physical differences between segments on a given measure may be subordinate to differences of greater magnitude or salience on other parameters which support the distinction more clearly. Thus, the small differences in F_0 which, *ceteris paribus*, correlate with the height of vowels are invariably subordinated to more significant uses of pitch variation signaling distinctions of tone, accent and intonation. Similarly, small differences in closure duration correlating with place of articulation of plosives are subordinated to much greater differences in duration forming single/geminate contrasts, as well as to variations related to position in an utterance, speech rate, etc. Hence vowels of different heights and plosives at different places are not considered to differ essentially in their F_0 or durations, but rather in the features defining their height and place. Differences in articulator height, one possible index of articulatory force, are principally allied with distinctions in 'sonority' — particularly between the aerodynamic states which characterize stops, fricatives, and approximants. This seems the dominant use of articulator height. Internal to such a sonority class, 'strength' differences seem to be subordinate in the senses discussed.

2. DAGESTANIAN LANGUAGES

However, some Dagestanian (N.E. Caucasian) languages may provide the evidence that strength is not always a subordinate or prosodic/pragmatic property. These languages have long been said to have distinctions between 'weak', and 'strong' consonants of certain classes (see [7] for a summary of Dagestanian phonetics). In certain cases, e.g. the word-medial stops and affricates of Archi, this seems simply to be a way of discussing a durational difference which others would call a single/geminate contrast, and one which moreover is closely tied to morphological alternations [4, 5]. But in other cases, e.g Archi fricatives in initial position, the distinction has a different character. In some cases 3-way intervocalic contrasts including a geminate are reported, as in Bagwala: /ˈbesa/ 'mountain', /reˈs̄el/ 'throat', /ˈhessa/ 'river.' ('Strong' consonants are transcribed with a macron without prejudice to their eventual phonetic description.) If confirmed, this would show independence of 'strength' and duration.

In what follows the phonetic nature of the reported 'strong'/'weak' contrast in three of the Dagestanian languages will be described based on partial analyses of substantial audio, aerodynamic and palatographic data on Bagwala and more limited audio and palatographic data on Dargi and Archi collected in 1997 in Kwanada and Maxachkala. The focus will be on voiceless fricatives because a) they seem to participate most widely in the contrast of interest, b) their acoustic duration corresponds closely to their articulatory duration, and c) fricative channel width appears an appropriate index of relative strength.

2.1 Bagwala

Bagwala is a language in the Avar-Andi group spoken in Kwanada and a number of neighboring villages. Fieldwork by Kibrik, Kodzasov and others (p.c.) suggests that a word-initial strong/weak contrast independant of gemination is found with fricatives and affricates. Geminates of these and other consonants manners occur word-medially, but there is no suggestion of a four-way contrast including both 'weak' and 'strong' geminates.

'Strong'/'weak' differences were investigated in initial position in the word pairs /sim/ 'lip' vs /s̄im/ 'bile' and /ˈʃija/ 'stook' vs /ʃ̄i/ 'milk', and in medial position in the triplet cited earlier. Figure 1 shows mean durations of the interval from frication onset to vowel onset in the word-initial examples. The 'weak' and 'strong' fricative durations are very little different from each other, suggesting that the distinction is not one primarily of duration, but lies elsewhere.

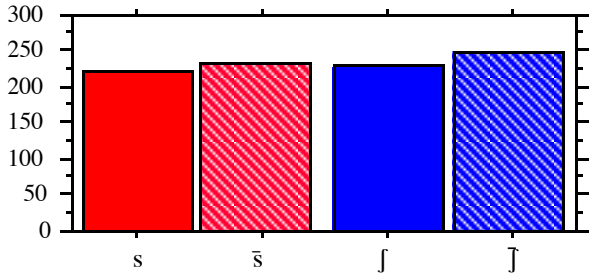

Figure 1. Bagwala initial fricative durations (2 tokens per type, from each of 5 speakers

However, this duration measure conceals a marked difference between the two classes. The 'weak' fricatives are quite audibly aspirated, the 'strong' ones lack aspiration. This difference is only occasionally apparent on spectrograms, as in those exemplified in Figure 2, but is consistently reflected in very different aerodynamic patterns, as exemplified in Figure 3. In both tokens, after an initial peak airflow drops and intra-oral pressure increases as the fricative constriction reaches its maximum. However, in the 'weak' /s/ airflow climbs to a much higher peak before the vowel onset. Since intraoral pressure measured behind the constriction location remains high at this time, the fricative constriction cannot yet have been fully released. This pattern suggests that an increase in subglottal pressure may be required to generate the higher flow through the constriction. In 'strong' /s̄/ on the other hand, no high airflow peak occurs prior to vowel onset, and the high intraoral pressure dissipates more slowly during the transition to the vowel.

Palatograms and linguograms, exemplified in figures 4 and 5, show that the escape channel for 'weak' /s/ at its most constricted point is wider than that for /s̄/ and that the lateral margins of the tongue contact are also further apart. In data from four speakers the constriction width observed on palatograms (expressed in normalized pixels) is significantly greater for /s/ than for /s̄/ ($F(1, 6) = 8.6$, $p = .026$). This suggests that there is indeed some difference in articulator height between these two segments. An interpretation of this difference is that a more open channel for weak fricatives goes some way toward facilitating the high airflow volume associated with the aspiration of these segments.

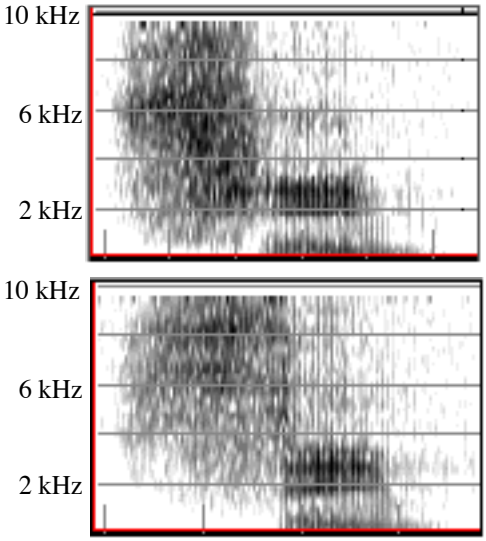

Figure 2. Sample spectrograms of Bagwala /sim/ 'lip' (top) and /s̄im/ 'bile' (bottom) (Speaker HI, duration 600 ms).

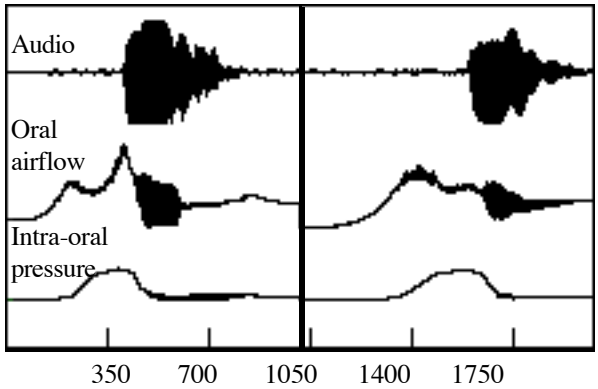

Figure 3. Sample aerodynamic records of Bagwala /sim/ 'lip' (left) and /s̄im/ 'bile' (right) (Speaker MH)

The aspiration of 'weak' /s/ is also found in intervocalic position. Figure 6 shows airflow and intraoral pressure records for the intervocalic consonants in /ˈbesa/ 'mountain', /reˈśel/ 'throat', and /ˈhessa/ 'river' for one speaker. Each trace is the average of 5 (for /ˈbesa/) or 6 repetitions aligned at the onset of the pressure rise. As in initial position, a marked peak in airflow well before vowel onset and an earlier decline in intraoral pressure are salient differences between /s/ and /s̄/. Both /s̄/ and the putative geminate /ss/ lack the peak and have a sustained high level of intra-oral pressure past the onset of the following vowel (visible in the figure as the time at which the averaged flow curves break into a scatter of points, reflecting pulsed flow through vibrating vocal folds). The slightly longer duration of the pressure peak in /ss/ seems likely to be attributable to the difference in stress placement, rather than to segment identity. The mean interval between offset of V1 and onset of V2 measured in the audio signal of these tokens is 232 ms in /reˈs̄el/ and 222 in /ˈhessa/, an insignificant difference (/ˈbesa/ at 207 ms is significantly different from /reˈs̄el/, $p = .0044$ by Fisher's PLSD, but /ˈhessa/ is not significantly different from the others).

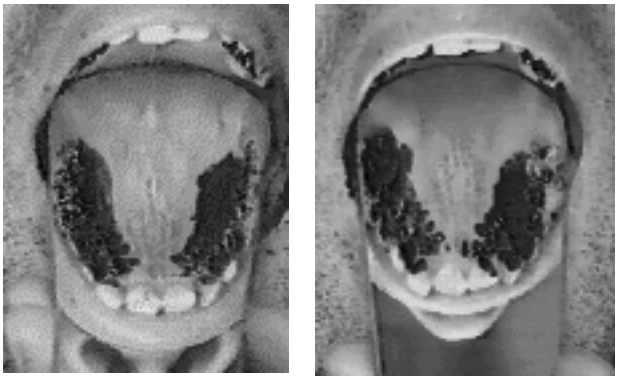

Figure 4. Samples of palatograms of Bagwala sim ‘lip’ (left) and s̄im ‘bile’ (right) (Speaker AZ)

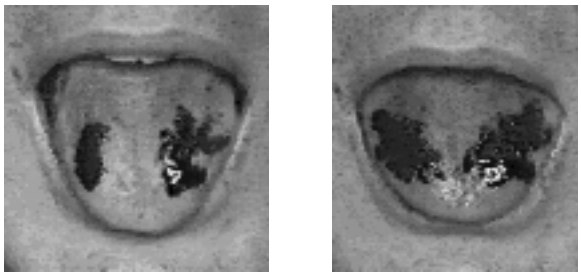

Figure 5. Samples of linguograms of Bagwala sim ‘lip’ (left) and s̄im ‘bile’ (right) (Speaker HI)

Thus, so far, our analysis of Bagwala does not confirm a phonetic distinction between geminate /ss/ and /s̄/. The palatographic and linguographic evidence also suggests, as exemplified in Figure 7, that the articulation of /ss/ is similar to /s̄/.

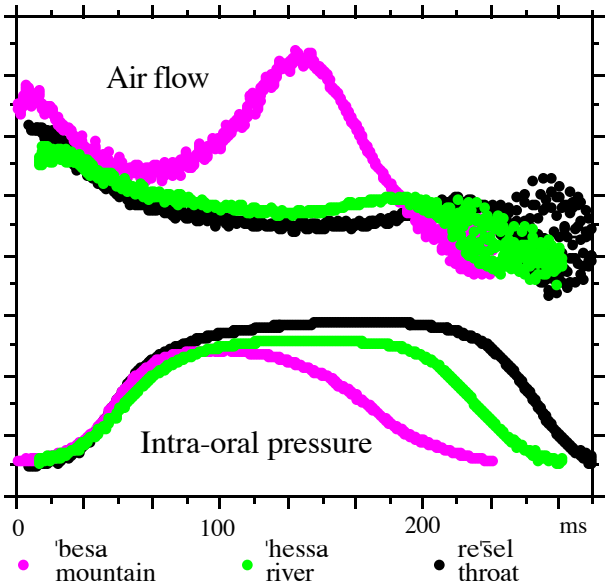

Figure 6. Comparison of airflow (top) and intra-oral pressure (bottom) in Bagwala intervocalic triplet, averages of 5 or 6 repetitions. (Speaker MH)

Figure 7. Linguogram of /ˈhessa/ (Speaker HI)

In summary, the analysis of Bagwala suggests it has only two voceless fricative categories. Their main difference lies in aspiration, that is, in parameters affecting laryngeal and pulmonic activity. The small differences in duration and the larger one in articulatory position are likely consequences of this aspiration difference rather than evidence that articulatory strength plays a major role in the contrast.

2.2 Dargi

Dargi is a language in the Lak-Dargi group which is marked by quite large dialectal variety. The variety investigated is from Itsari. Dargi is reported to have strong/weak contrasts among its voiceless stops, affricates and fricatives. Audio, palatographic and linguographic data was collected from three speakers. Results are presented for word-initial coronal fricatives only. The word pairs /sa/ ‘in depth’ vs /s̄a/ ‘yesterday’ and /ʃam/ ‘young ram’ vs /ʃ̄a/ ‘in the village’ or /ʃ̄i/ ‘village’ were investigated. There is a highly significant difference in the frication duration of these ‘weak’ and ‘strong’ fricatives ($F(1, 57) = 32.3$, $p < .0001$), but the magnitude of the difference, 161 vs 200 ms, is considerably smaller than might be expected for a single/geminate contrast in this position if values given by Abramson [1] for Pattani Malay are representative. Mean durations of the segments investigated are given in Figure 8.

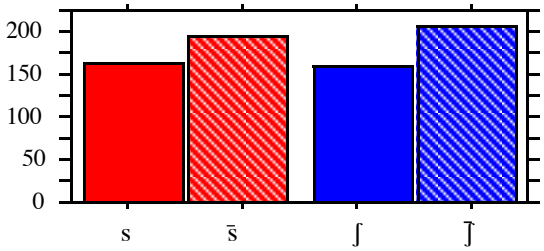

Figure 8. Mean word-initial fricative durations in Dargi (5 tokens per type x 3 speakers)

In contrast to Bagwala, there is no strong percept of aspiration of the ‘weak’ fricatives, yet there are noticeable differences in articulatory position between weak and strong counterparts. Figure 9 shows the wider escape and lesser lateral contact in the ‘weak’ post-alveolar fricative /ʃ/ compared to its ‘strong’ counterpart for speaker AM. The modest durational difference and the absence of aspiration suggest that articulator height may indeed be a major aspect of this distinction in Dargi.

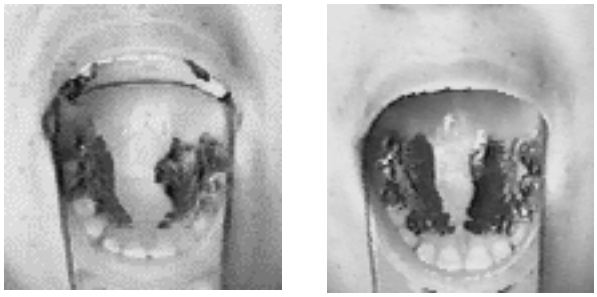

Figure 9. Sample palatograms of Dargi fricatives in /ʃam/ ‘young ram’ (left) and /ʃ̄a/ ‘in the village’ (right).

2.3 Archi

Archi is a language in the Lezgian group spoken in one main village north of the principal Lezgian area. Archi stops and affricates participate in what is fairly clearly a single/geminate contrast, with the geminates only appearing word-medially [6]. Voiceless fricatives on the other hand show a contrast of two categories in word-initial position. This initial contrast of fricatives has generally been conflated with the intervocalic single/geminate distinction and both labeled ‘weak’ vs ‘strong.’

The results for Archi are similar to those for Dargi. Figure 10 shows the mean durations of the frication in the words /ˈsaku/ ‘roe deer’, /s̄ap/ ‘wild onion’ and /s̄am/ ‘bile’ measured in 3 repetitions of each word by 4 speakers. These means (186 vs 229 ms) are significantly different ($F(1, 33) = 15.1$, $p = .005$), but the size of the difference is not large. For the two of these speakers who provided a good set of palatograms the escape channel size is quite markedly different between /s/ and /s̄/. Figure 11 shows sample palatograms of /s/ in /baˈsa/ ‘when’ and /s̄/ in /s̄am/ ‘bile’ and Figure 12 the width in mm calculated for the narrowest part of the channel in these words for the two speakers AM and AH.

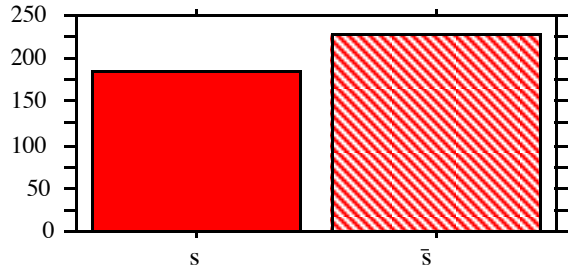

Figure 10. Mean frication durations of /s/ and /s̄/ in Archi.

Figure 11. Sample palatograms of Archi /s/ in /baˈsa/ ‘when’ (left) and /s̄/ in /s̄am/ ‘bile’ (Speaker AM).

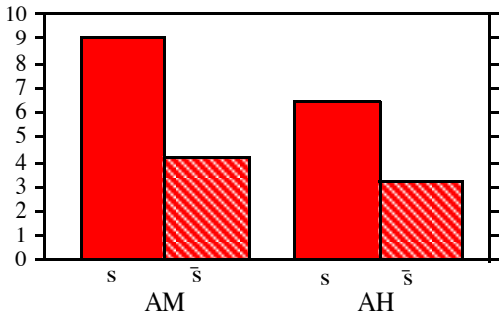

Figure 11. Channel width in mm of /s/ and /s̄/ for two speakers of Archi.

3. SUMMARY

The phonetic realization of the ‘strength’ distinction in fricatives includes variation of constriction degree while remaining within the limits of the critical range for friction. This distinction may indeed be the principal factor distinguishing ‘strong’ from ‘weak’ fricatives in Dargi and Archi. But in Bagwala ‘strength’ might best be regarded as subordinate to laryngeal settings.

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NOTES

1. The ‘fortis’ consonants of Korean were set aside as being distinguished by additional respiratory force and tract wall stiffness, as well as a constricted laryngeal setting, not articulatory strength.

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