HOW UNIVERSAL IS THE SONORITY HIERARCHY?: A CROSS-LINGUISTIC ACOUSTIC STUDY

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ABSTRACT

This paper examines the universality of the acoustic basis for the sonority hierarchy: glides > liquids > nasals > obstruents in four genetically diverse languages: Egyptian Arabic, Hindi, Mongolian, and Malayalam. It is shown that disputed sonority contrasts, such as a) laterals vs. rhotics, b) voiceless fricatives vs. voiced stops, c) affricates vs. stops, and d) sibilants vs. other fricatives, follow language-specific patterns, while undisputed contrasts, such as sonorants > obstruents, are cross-linguistically consistent in their acoustic patterns. Differences in sonority as a result of prosodic position and interspeaker variation are not observed in the present study.[1]

Keywords: sonority; sonority hierarchy; intensity

1. INTRODUCTION

This paper examines the universality of the acoustic basis for the sonority hierarchy: glides > liquids > nasals > obstruents in four genetically diverse languages: Egyptian Arabic, Hindi, Mongolian, and Malayalam. The acoustic basis for sonority is defined in terms of intensity.

Parker [11] explores the hypothesis that phonological sonority has concrete quantifiable physical correlates. He measures five potential acoustic and aerodynamic correlates of sonority for Spanish and English: intensity, peak intraoral air pressure, first formant values, peak air flow, and total duration. Parker [11] concludes that intensity is the most reliable correlate of phonological sonority while duration is the weakest correlate. This coincides with Ladefoged's [10] definition of sonority: 'The sonority of a sound is its loudness relative to that of other sounds with the same length, stress, and pitch', which is based on intensity or the perceived loudness of a sound. According to Parker [11], sonority is best defined as a linear regression equation derived from intensity measurements. For the Spanish female speakers, the population displaying the closest correlation between acoustic intensity and sonority, Parker proposes the following formula to calculate sonority:

(1) $\text{sonority} = 5.16 + .37 \times \text{dB}$

This formula is applied here to examine the sonority hierarchy in acoustic terms.

There is ample phonological evidence for the sonority hierarchy based on the internal structure of the syllable, such as the sonority sequencing principle (Blevins [2], Clements [3], Harris [7]), the minimum sonority distance (Selkrik [13], Steriade [14]), the sonority dispersion principle (Clements [3], [4]), and sonority based stress (Bianco [1], de Lacy [5], [6]). The phonological sonority hierarchy is assumed to be universal. Acoustic studies of sonority, on the other hand, are characteristically limited to case studies of individual languages (Price [12], Keating [8], [9], Parker [11]). The current study sheds some light on cross-linguistic similarities and differences in acoustic sonority and examines the phonetic basis for disputed rankings in the sonority hierarchy.

There is widespread disagreement among linguists about the natural classes that need to be distinguished in terms of sonority. Disputed sonority contrasts include the following: laterals vs. rhotics, fricatives vs. stops, voiced vs. voiceless obstruents, voiced stops vs. voiceless obstruents or voiceless fricatives, and affricates vs. stops vs. fricatives, among others. Furthermore, it has been suggested that sibilants merit a special position in the hierarchy separate from other obstruents (Parker [11]). In the current study, the ranking of each of these classes of sounds is studied for each of the four languages. In addition, differences in sonority as a function of prosodic position (onset vs. coda position) and interspeaker variation are examined. Parker's [11] measurements yield similar results across speakers, genders, and prosodic positions.

2. METHODOLOGY

Four languages with different phoneme inventories and different phonetic realizations of their phonemes were targeted for investigation: Egyptian Arabic, Hindi, Mongolian, and Malayalam. For each language, a list of disyllabic words was compiled in which the first syllable was systematically varied to include all possible codas. The list of codas for each language is shown in Table 1.

Table 1: List of codas

Language	Codas
Egyptian Arabic	b, d, dˤ, dʒ, ð, f, θ, ɣ, h, ħ, j, k, l, m, n, q, r, s, sˤ, ʃ, t, tˤ, w, x, zˤ
Hindi	k, kʰ, g, gʰ, ʈ, ʈʰ, ɖ, ɖʰ, t, tʰ, d, dʰ, p, pʰ, b, bʰ, tʃ, tʃʰ, dʒ, dʒʰ, r, l, ɽ, ɽʰ, s, ʃ, z, f, y, w, h, m, n
Mongolian	b, d, g, m, n, ŋ, s, ʃ, r, l, t, x, dz, dʒ, ts, tʃ, p, k
Malayalam	k, kʰ, g, gʰ, tʃ, dʒ, ɳ, t, d, dʰ, n, p, b, bʰ, m, y, r, l, v, ʂ, s, h

Syllable nuclei contained low vowels. In order to compare results across languages, the codas of the first syllable, as well as the onsets of the second syllable, were examined, thereby avoiding word-initial and word-final position, positions prone to phonetic lengthening. Each word was recorded five times in a carrier phrase by four to six speakers, both male and female (see Table 2). Data were recorded in a soundproof booth on DAT tape using a high quality unidirectional microphone.

Table 2: Recordings of target words

Language	Speakers
Egyptian Arabic	3 male + 1 female
Hindi	4 male + 1 female
Mongolian	2 male + 4 female
Malayalam	1 male + 3 female

Acoustic analysis was conducted using Praat (www.praat.org). Mean intensity over the entire segment was measured for each consonant in coda and in onset position. The acoustic sonority was then defined as a linear regression equation derived from the intensity measurements using Parker's formula established for the female Spanish speaker. The results were entered into SPSS, software for statistical analysis, and coded for various variables, including consonant voicing, consonant class (laterals, rhotics, nasals, stops, glides, fricatives excluding sibilants, sibilants, and affricates), speaker, gender, and prosodic position.

In order to allow for interspeaker and interlanguage comparison, the sonority values for each of the measured consonants for a single speaker were divided by the highest value. These values were then used to establish the relative sonority ranking value for each consonant. These numbers were compared across speakers within one language, as well as cross-linguistically.

3. RESULTS

For each language a series of independent variables was examined: a) prosodic position, b) speaker and gender, and c) ranking of each consonant class in the hierarchy across speakers. Disputed sonority contrasts were given special attention in the evaluation of the results.

3.1. Results for Egyptian Arabic

Egyptian Arabic shows no major interspeaker variation in the sonority hierarchy. The hierarchies are roughly the same in coda and in onset position with some minor shifts within the sonorant category (compare Figures 1 and 2). As universally predicted, voiceless obstruents are ranked lower in the hierarchy than their respective voiced counterparts, i.e. voiceless fricatives < voiced fricatives, voiceless sibilants < voiced sibilants, voiceless stops < voiced stops (not shown separately). Laterals are ranked slightly higher than rhotics and sibilants higher than other fricatives. The results for coda position produce the following sonority hierarchy with a clear difference between sonorants (the first four classes) and obstruents (the last four classes): laterals > nasals > glides > rhotics > affricates > sibilants > fricatives (excluding sibilants) > stops, as seen in Figure 1.

While stops are ranked lower in the hierarchy than fricatives, voiced stops show higher values than voiceless fricatives. The results coincide with the universal sonority hierarchy, except for glides which show slightly lower values than laterals and nasals. In onset position, laterals are ranked clearly higher than other sonorants. Overall, Egyptian Arabic shows no exceptional patterns and variations due to prosodic position are minor.

Figure 1: Sonority results for codas in Arabic

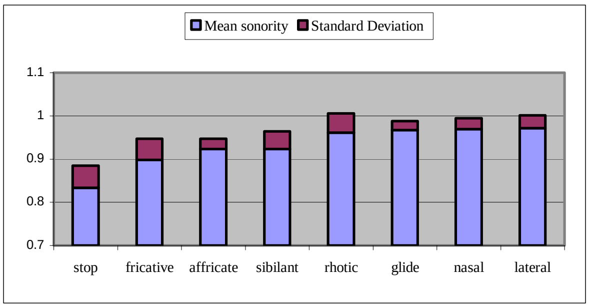
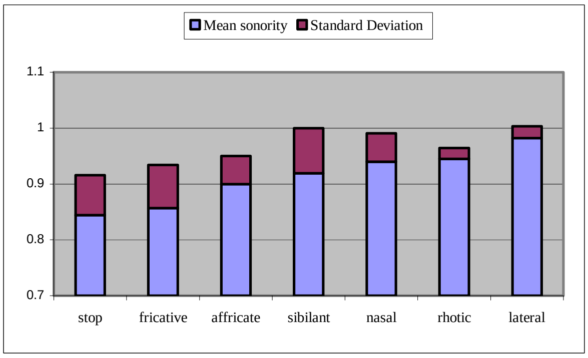


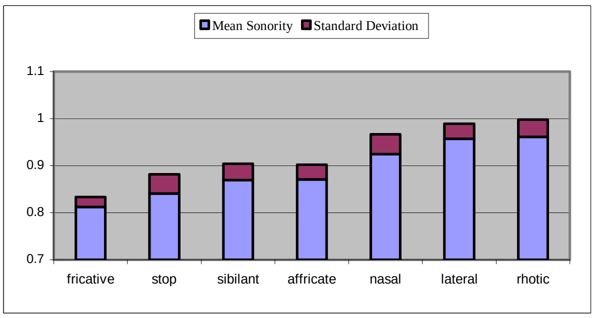
Figure 2: Sonority results for onsets in Arabic



3.2. Results for Hindi

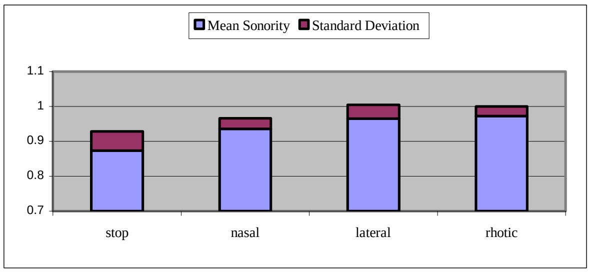
Similar to Egyptian Arabic, the results for Hindi do not indicate any major variation due to speaker, gender, or prosodic position. As expected, voiceless obstruents are ranked lower than their respective voiced counterparts, i.e. voiceless sibilants < voiced sibilants, voiceless affricates < voiced affricates, voiceless stops < voiced stops. The sonority hierarchy in coda position is: laterals > rhotics > nasals > affricates > sibilants > stops > fricatives, as seen in Figure 3.

Figure 3: Sonority results for codas in Hindi



Interestingly, stops, including both voiced and voiceless subclasses, are ranked higher than non-sibilant fricatives in the hierarchy. This may be due to a combination of two factors. First, Hindi has phonemic aspirated stops, which have a perceptually prominent release that was included in the measurements. Furthermore, the only non-sibilant fricative in Hindi is /f/, which is generally ranked low in the universal sonority hierarchy. Fewer classes were examined in onset position where rhotics ranked the highest, as in Figure 4. The results indicate a clear difference between sonorants and obstruents. Rhotics and laterals differ only minimally and the overall rankings coincide with the universally established sonority hierarchy.

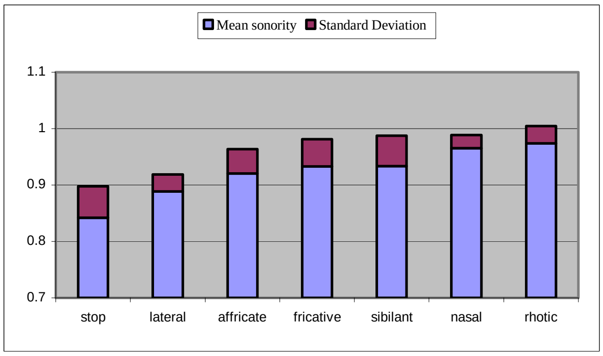
Figure 4: Sonority results for onsets in Hindi



3.3. Results for Mongolian

Results for Mongolian, parallel to those for Egyptian Arabic and Hindi, do not show major interspeaker variation or substantial differences due to prosodic position.

Figure 5: Sonority results for codas in Mongolian



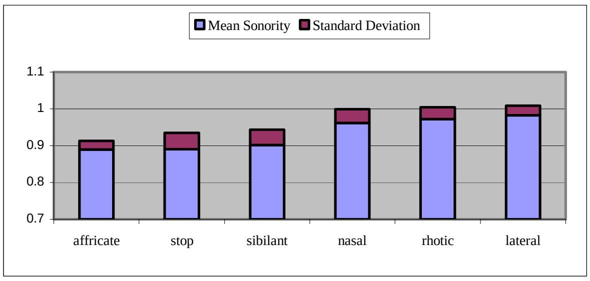
In Mongolian, laterals are ranked lower than might be expected due to their phonetic realization as fricatives, i.e. /l/ is pronounced as [ɬ] or [ɮ]. Even within the class of fricatives, their values are much lower than those of the other fricatives. The results indicate the following sonority hierarchy: rhotics > nasals > fricatives (excluding sibilants), sibilants >

affricates > laterals > stops. While voiceless obstruents are ranked lower than their voiced counterparts, voiceless affricates show slightly higher values than their voiced counterparts, which may be due to the acoustic prominence of the voiceless sibilant. Except for the laterals, the sonority hierarchy shows no exceptional patterns in Mongolian.

3.4. Results for Malayalam

In Malayalam the sonority hierarchy shows no exceptional rankings: laterals > rhotics > nasals > sibilants > affricates > stops, as in Figure 6. However, the difference between laterals, rhotics, and nasals, as well as between sibilants, affricates, and stops, is minimal. Therefore, the hierarchy can be merged to laterals, rhotics, nasals > sibilants, affricates, stops or to sonorants > obstruents. No major differences due to prosodic position or interspeaker variation were identified.

Figure 6: Sonority results for codas in Malayalam



3.5. Summary and cross-linguistic comparison

The multi-language acoustic analysis of sonority in the present study is consistent with other work on phonetic correlates of sonority (Clements [3], Parker [11]). Nevertheless, results indicate that relative values for the different consonant classes vary greatly cross-linguistically.

4. CONCLUSIONS

Except for Mongolian, the universal sonority hierarchy: glides > liquids > nasals > obstruents is largely maintained in the languages examined. Glides only appear in Arabic. While sonorants show minor cross-linguistic differences, obstruents are more prone to language-specific patterns. Disputed rankings in phonological sonority, such as laterals vs. rhotics, voiceless fricatives vs. voiced stops, affricates vs. stops, and sibilants vs. other fricatives, are mirrored by language-specific differences in acoustic sonority, while undisputed rankings in phonological sonority correspond to more consistent phonetic rankings. Differences in sonority as a result of prosodic position and interspeaker variation are not observed.

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