THE ACQUISITION OF HUNGARIAN VOWELS DIFFERING IN PHONEMIC VOWEL LENGTH

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ABSTRACT

This study examined spectral properties of five Hungarian vowel pairs with contrasting phonemic vowel lengths in 2;0 and 4;0 years old boys acquiring Hungarian as their native language. Results were obtained by an automated pitch-synchronous bandfilter analysis method that estimates the spectral envelope representation of vowels. Subsequent data reduction was achieved via principal component analysis.

Findings show that 4;0 years olds produce more adult-like vowels due to an increased ability to formulate more peripheral and more rounded vowels. As a result, the vowel space of older children contains more differentiated vowel categories, with more compact vowel spaces corresponding to each vowel. The spectral differentiation of short vs. long vowel pairs is more adult-like in 4;0 years olds than in younger children, but the acquisition of spectrally differentiated vowels with contrasting vowel length is not yet complete at this age.

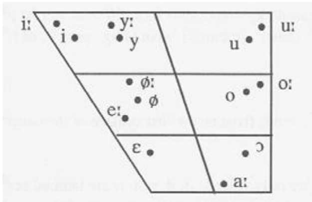
Keywords: vowels, acquisition, children, Hungarian, phonemic vowel length, spectral differentiation.

1. INTRODUCTION

Many languages code differences in meaning by using contrasting phonemic vowel length. In the UPSID317 database, 19.6% of the languages examined apply this differentiation to allow for semantic identification [1]. The standard dialect of Hungarian, a Finno-Ugrian language uses a two-way phonemic vowel length contrast that is characterized by an average duration ratio of 1:2 [2], [3]. Standard Hungarian uses phonemic vowel length as a primary feature to differentiate five of its seven vowel pairs: /i/ vs. /i:/, /o/ vs. /o:/, /ø/ vs. /ø:/, /u/ vs. /u:/ and /y/ vs. /y:/. Further, the members of these vowel pairs are also differentiated by a secondary distinguishing feature of spectral contrast. (Members of the remaining two vowel pairs, /ɔ/ vs. /a:/ and /ɛ/ vs. /e:/, are contrasted by both durational and substantial spectral differences; for the acoustic representation of the Standard Hungarian vowel space, see Fig. 1.)

This study examines the acquisition of spectral differences in the five Hungarian vowel pairs that are primarily differentiated by durational cues and are characterized by subtle spectral differences. The objective was to map out developmental trends in the acquisition of spectral differentiation between phonemically short vs. long vowels.

Figure 1. The vowel space of Standard Hungarian (modified from Szende [4]).



2. METHODOLOGY

This study applied a cross-sectional study design. The study is part of a larger research project that explores vowel acquisition processes in children cross-linguistically; for details of setup and procedures, see [5], [6], [7], [8].

2.1. Participants

Participants included 5-5 boys at the age of 2;0 years and 4;0 years (± 2 weeks from birthday). The children and their caregivers were monolingual native speakers of the standard dialect of Hungarian from the Budapest area, without substantial exposure to other dialects or languages. All children had an uneventful health history.

2.2. Experimental setup and procedures

Participants and their caregivers were instructed to play with stuffed animals in a sound attenuated room (~ 6 m^2). Toys had pre-assigned CV(:)1CV(:)1 structured names sawn on their back to help the caregiver recall them. Caregivers attempted to elicit the production of tokens from each child at least five times during a naturalistic interaction. Animal names included /pipi/ vs. /pi:pi:/, /lolo/ vs. /lo:lo:/, /gøgø/vs. /kø:kø:/, /bubu/ vs. /pu:pu:/, and /nyny/ vs. /my:my:/. Tokens with short vs. long target vowels were recorded during two separate sessions that were scheduled for no more than two weeks apart.

2.3. Recording procedure and data selection

The Sound Forge acoustic software (Version 5.0, Built 117) was used to record the speech samples (recording attributes: 32 kHz, 16 bit, mono). Data selection was carried out by a monolingual Hungarian speaker. Only tokens that were produced in relative proximity to the elicitation by caregivers containing two correctly produced vowels were selected perceptually. A second judge rated 10% of the dataset for reliability. Inter-rater agreement for each vowel category exceeded 90%.

2.4. Data analysis

Data analysis was carried out by using an automated pitch-related bandfilter analysis method that allows for an acoustically unbiased measurement of formant measures. The method estimates the spectral envelope representations of vowels. All selection and analysis procedures were carried out by scripts in the Praat acoustic software program [9].

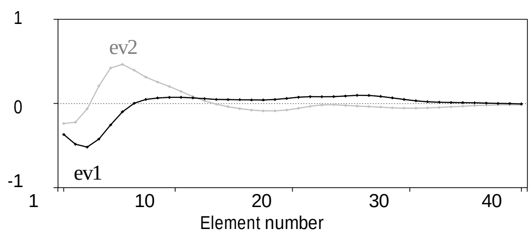
Individual $CV(:)_1CV(:)_1$ productions were analyzed as unlabeled tokens. Specified intensity criteria were used to avoid clipped segments and low intensity fragments. To bandfilter the selected part, the F_0 period nearest to the selection was recirculated to generate a sufficiently long signal. Signal filtering was carried out by the application of a Gauss bandfilter, tuned to 0-7kHz in 40 steps of 175 Hz. Bandwidth was set to 1.1 x 425 Hz. The resulting spectral envelope contains spectral intensities of 40 adjacent frequency bins of 175 Hz width. Each measurement represents a point in a 40 dimensional space.

Principal component analysis was used to reduce the data set. This approach has been used successfully to generate vowel production charts in both adults [10], and children [7], [8], [9], [11]. A new space was then generated, with pc1 representing the component with the largest variance and pc2 representing the component with the second largest variance, etc. The first two principal components created a vowel space with pc1 showing resemblance to F2 and pc2 showing resemblance to F1 (see Figures 3A-B to 7A-B in the attachment file).

3. RESULTS

To compare vowel categories in 2;0 and 4;0 years old children, a pc1-pc2 reference plane was created by using data from all 4;0 years old boys. Vowel spectra measures from 687 $CV(:)_1CV(:)_1$ tokens that included each of the 14 Hungarian monophthongs from all 5 boys were analyzed to create a pc1-pc2 plane. The plane, which is defined by a set of eigenvectors, includes 4372 measurement points indicated by grey plus signs in the figures. The first eigenvector explains 26.2% of variance, while the second one explains 18.9% of variance (see Figure 2.). Thus, the cumulative percentage of variance explained by the first two eigenvectors is 45.1%. To determine the location of the corner vowels within the vowel space, labels containing the vowels /i(:)/, /u(:)/ and /ɔ/ were analyzed and projected onto the reference plane.

Figure 2. The first two eigenvectors of the Standard Hungarian reference space/plane.



Children's labeled tokens were analyzed according to the target token. To determine the location and dispersion of each vowel category within the reference plane, a randomly selected 60 measurement points from each category were projected onto the pc1-pc2 reference plane. An ellipse was created for each category that represents 1 SD from the mean of the measured variance. Results are shown in Figures 3A-B to 7A-B; "A" figures contain data from 2;0 year-olds; "B" figures are from 4;0 year-olds.

4. DISCUSSION

A number of production characteristics and developmental tendencies are shown by the data. Results are reviewed by comparing the acoustic properties of individual vowel categories both within and between age groups.

4.1. /i/ vs. /i:/

At 2;0 years, boys produce quite centralized vowels. However, phonemically short vowels are more centralized, indicating less stability of production patterns in comparison to phonemically long vowels. In contrast with the long vowels, the majority of short vowels are realized with lower jaw position. Ellipses areas (3.95 vs. 2.59, resp.) show that, during long vowel production children hit a more concentrated target area of the vowel space more consistently. Children have more time to position their articulators to the required position in these cases, and long vowels are thus more adult-like. See Fig. 3A.

At 4;0 years, both vowels are realized with a higher jaw position. Centralization tendencies are diminished. The areas of the ellipses (1.69 vs. 2.31) indicate more consistency in the production of the short vowel. It is reasonable to speculate that long vowel duration results in changing vowel spectra, reflected by a more sizeable ellipse showing 1SD from the mean of measured variance. See Fig. 3B.

Developmentally, vowels produced by older children are more adult like, even though producing the vowels in a front position is still a challenge. The corner vowel position is being hit less frequently, showing difficulties with fronting.

4.2. /o/ vs. /o:/

At 2;0 years, boys realize mid vowels in a low position, indicating an inability to round lips. The majority of short vowels are realized with a lower jaw position. Phonemically long vowels are more centralized, indicating less stability of production patterns in comparison to phonemically short vowels and prominent error patterns (e.g., o > ɔ, o > ɛ). The area of the ellipses (5.93 vs. 4.87, resp.) indicate that, during the production of the long vowels children hit a less concentrated target area of the vowel space with more consistency. However, while producing long vowels, children have difficulties with trying to position and keep their lips rounded, resulting in unstable (changing) production characteristics. Neither the short nor the long vowels are adult-like. See Fig. 4A.

At the age of 4;0, boys produce mid vowels by covering a more sizeable area of the vowel space, as shown by the area of the ellipses (6.41 vs. 5.46, resp.). Many long vowels are produced in more peripheral position, indicating that during a longer duration boys hit the target area of the vowel space more often. Producing long vowels with higher jaw positioning is a property of the adult vowel system, making production patterns more adult-like in older children. See Fig. 4B.

Developmentally, older children produce more adult-like vowels, due to an ability to a) produce the vowels with higher jaw position, and b) spectrally differentiate the short vs. long vowels. Overall, the production of the vowels in 4;0 years old boys is not yet adult-like, due to an inability to produce all vowels with a back tongue position more consistently.

4.3. /ø/ vs. /ø :/

At 2;0 years of age, boys realize front mid vowels in centralized position, indicating not yet fully developed skills to round lips. The majority of long vowels are realized with a lower jaw position. Prominent error patterns (e.g., ø(:) > o, ø(:) > ɔ, ø(:) > ɛ) show difficulties with a) lip rounding and b) coordinating lip rounding with front tongue position. The areas of the ellipses (6.41 vs. 5.46, resp.) indicate that, during the production of the long vowels children hit a less concentrated target area of the vowel space with less consistency. That is, while producing long vowels, children have difficulties with trying to position their lips into a rounded position, resulting in a unstable (changing) production characteristics. Neither the short nor the long vowels are adult-like. See Fig. 5A.

At 4;0 years, many short vowels are produced in a considerable more frontal position, while long vowels are typically produced in a central position. Additionally, the majority of vowels are produced with a higher jaw position. The areas of the ellipses (4.91 vs. 4.78, resp.) show similar consistency for both short and long vowels in hitting a more restricted area of the vowel space. Higher consistency in aiming at a smaller acoustic sub-space indicates more stable speech production patterns, including a higher ability to round lips. See Fig. 5B.

Developmentally, older children's vowels are more adult-like, due to an ability to produce vowels with higher jaw position and more prominent lip rounding. Further, the spectral differentiation of short vs. long vowels (whereas long vowels are produced with higher jaw position) makes older children's vowels more adult-like. However, the production of long vowels with a less (rather than more) frontal tongue position shows that the differentiation of the two vowels is not carried out in a completely adult-like fashion in 4;0 years olds.

4.4. /u/ vs. /u:/

At 2;0 years, boys realize many high back rounded vowels in a mid back position, clearly showing a non-adult-like ability to coordinate lip rounding with high jaw positioning during vowel production. The majority of long vowels are realized with a lower jaw position, indicating instability of production patterns and a prominent error pattern (u(:) > o). The areas of the ellipses (5.24 vs. 6.50, resp.) show that the longer vowel duration results in more varied spectral characteristics. Clearly, formulating and sustaining lip rounding for a longer duration is a challenge at this age. See Fig. 6A.

At 4;0 years, boys produce the short vowels in a high back position, reflecting relatively more mature skills in lip rounding (ellipse areas are 5.60 vs. 3.70, resp.). Similarly to the 2;0 year-olds, older children are less successful with hitting a more compact area of the vowel space when producing vowels with longer duration. Longer duration appears to be associated with less stable vowel production patterns, indicating non- adult-like abilities to maintain rounding. See Fig. 6B.

Developmentally, older children's vowels are more adult-like, due to an improved ability to round the lips and more success with producing these vowels with a high jaw position. However, spectral differentiation of the members of the vowel pair does not appear adult- like since the long vowels are produced with a lower jaw position and more frontal tongue position.

4.5. /y/ vs. /y:/

At 2;0 years of age, boys appear to centralize both the short and long high front vowels. Even though Hungarian does not have a phonemic schwa sound, the acoustic quality of these vowels is similar to that of a reduced vowel. The areas of the ellipse (4.48 vs. 4.31, resp.) indicate similar production patterns for both vowels. Spectral differentiation is minimal. See Fig. 7A.

At 4;0 years, the majority of vowels are produced in a high central position, indicating strong error patterns (e.g., y(:) > u, y(:) > i). Long vowels have a stronger tendency to be substituted by /u/, showing the challenging nature of coordinating more frontal tongue positioning with lip rounding. The difference in the areas of the ellipses (2.94 vs. 3.83) clearly shows the prominence of this error pattern. See Fig. 7B.

Developmentally, these vowels reflect the most progress towards adult-like vowel production in boys between 2;0 and 4;0 years of age. However, the spectral differentiation of vowels with contrasting phonemic vowel length is not yet adult-like in 4;0 years old boys: the more posterior production of long vowels show vowel production mechanisms in older children that are not yet mature.

5. SUMMARY

Examining the spectral differentiation of vowels with contrasting phonemic vowel length is important when formulating a theory of vowel acquisition since the realization of these spectral differences show the extent of the acquisition in children. Results show that the vowel acquisition process is clearly not completed in 4;0 years old boys acquiring the standard dialect of Hungarian, as reflected by non-adult-like spectral patterns in children's vowels differing in phonemic vowel length.

Overall, vowels produced by 4;0 years old boys are closer to the adult model, due to 1) an increased ability to produce vowels with higher (more closed) jaw position, 2) increased skills for formulating lip rounding, 3) an ability to maintain stable lip rounding for longer durations, and 4) skills to coordinate lip rounding with higher and more frontal tongue positions. In general, the more compact ellipse areas of individual vowel categories in older children are indicative of higher level speech skills used during vowel production.

Figure 3A

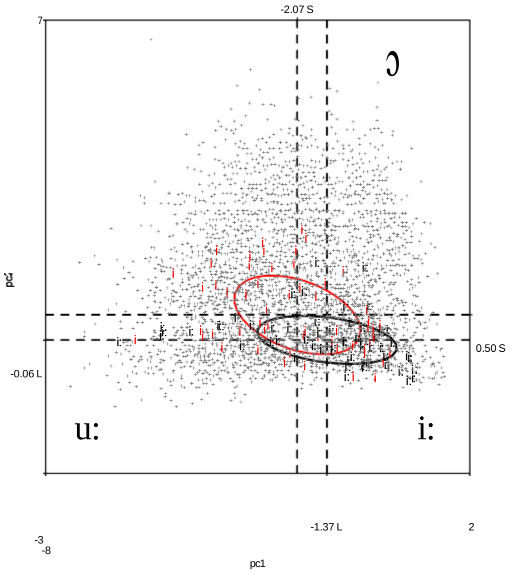


Figure 4A

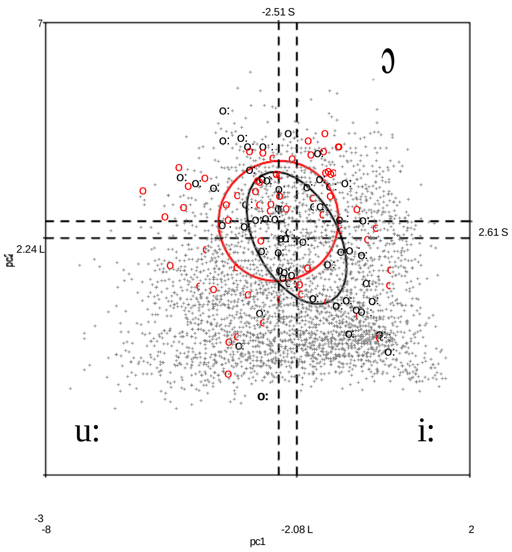
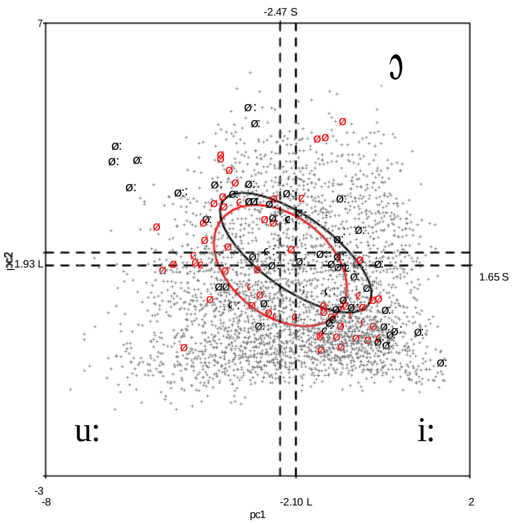


Figure 5A



Vowels of 2;0 years olds (3A: /i/ vs. /i:/, 4A: /o/ vs. /o:/, 5A: /ø/ vs. /ø:/) projected onto the reference plane. Each ellipse represents 1 SD from the mean of measured variance. Red/grey: short; Black: long; S: short; L: long vowels.

Figure 3B

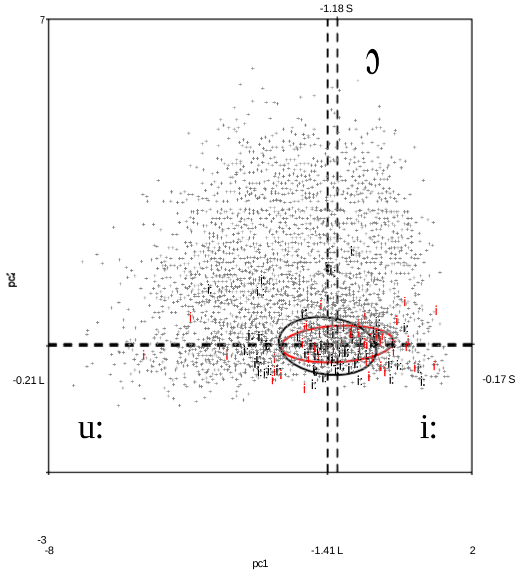


Figure 4B

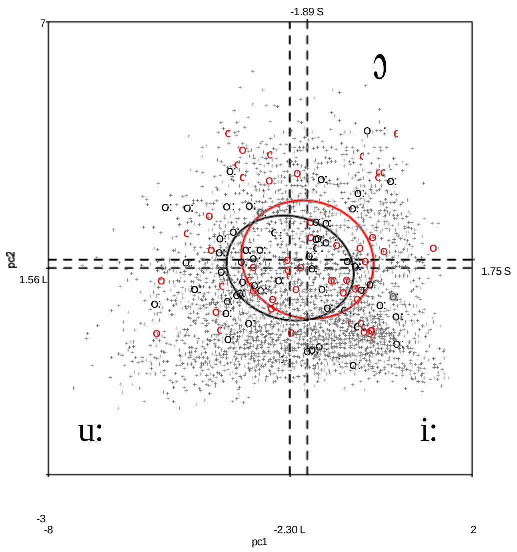
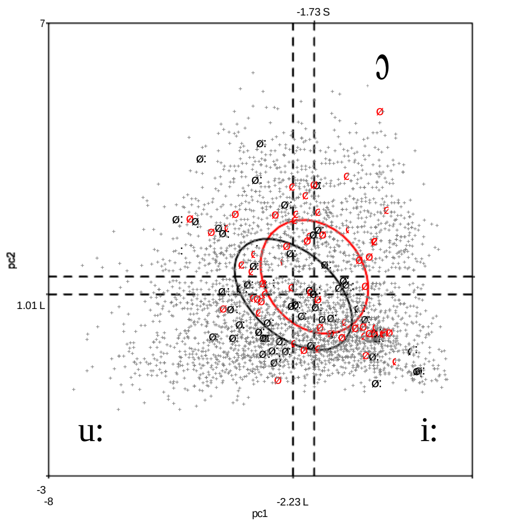


Figure 5B



Vowels of 4;0 years olds (3B: /i/ vs. /i:/, 4B: /o/ vs. /o:/, 5B: /ø/ vs. /ø:/) projected onto the reference plane. Each ellipse represents 1 SD from the mean of measured variance. Red/grey: short; Black: long; S: short vowels; L: long vowels.

Figure 6A

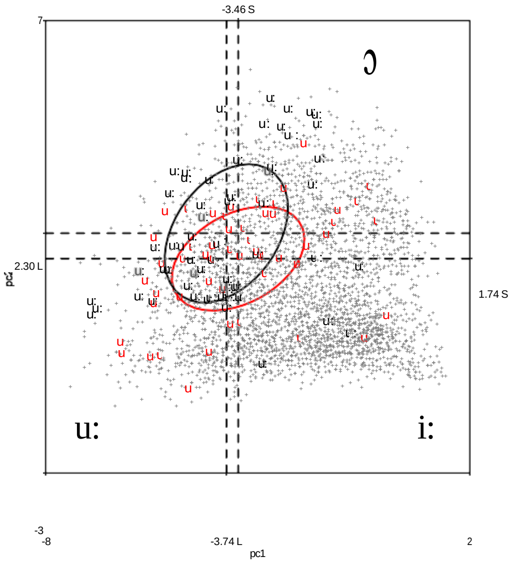


Figure 6B

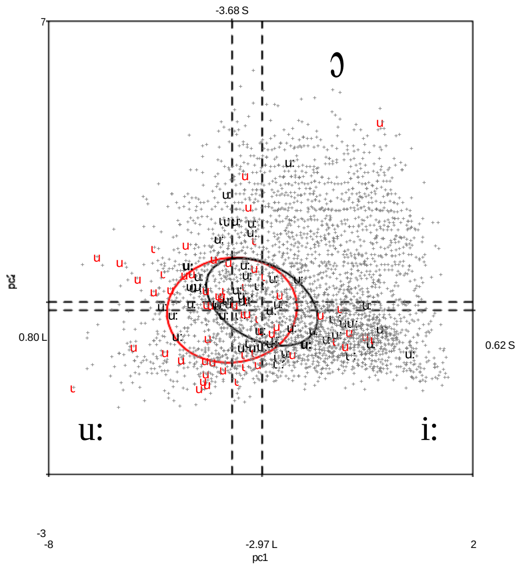


Figure 7A

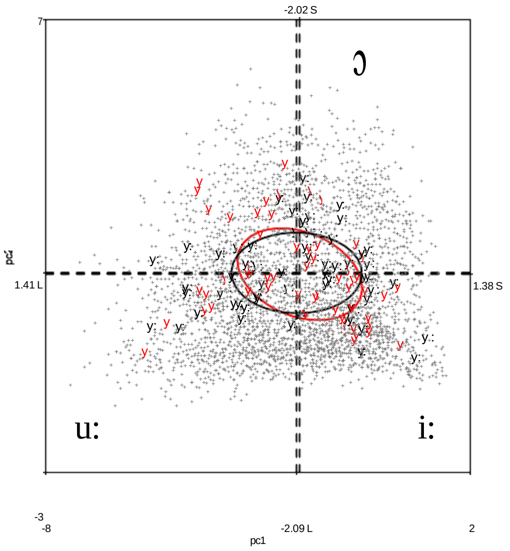
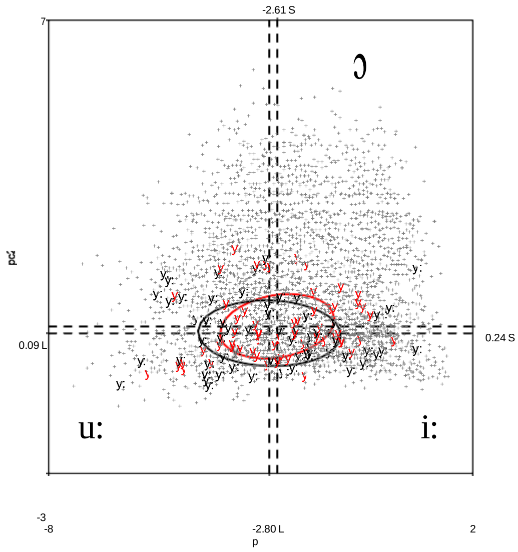


Figure 7B



Vowels of 2;0 years olds (6A: /u/ vs. /u:/, 7A: /y/ vs. /y:/) projected onto the reference plane. Each ellipse represents 1 SD from the mean of measured variance. Red/grey: short vowels; Black: long vowels. S: Short vowels, L: long vowels.

Vowels of 4;0 years olds (6B: /u/ vs. /u:/, 7B: /y/ vs./y:/) projected onto the reference plane. Each ellipse represents 1 SD from the mean of measured variance. Red/grey: short vowels; Black: long vowels. S: short vowels, L: long vowels.

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