

Production and perception of Greek vowels in normal and cerebral palsy speech

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Abstract

This study investigates the perceptual consequences and differences in vowel production between cerebral palsy (CP) afflicted Greek speakers and their normal counterparts. Formant (F1 and F2) values for the five vowels of Modern Greek were extracted from productions of both male and female speakers in stressed and un-stressed conditions. These same productions were presented to normal hearing Greek speakers for vowel identification. Aggregate vowel spaces constructed from the mean F1 and F2 values reveal that the male CP speakers' productions more closely resemble normal female spaces than that of normal males, but has only a slight impact on reducing intelligibility. Unstressed vowel productions from female CP speakers reduced intelligibility most significantly, in particular for the vowel [o]. Significantly greater standard errors around formant means for the CP speakers' unstressed vowel productions suggest these speakers have considerably more difficulty in controlling vocal tract shape when using less vocal effort.

Introduction

This is an experimental investigation of vowels in Greek as a function of mobility (intact versus cerebral palsy afflicted system), gender, stress and vowel category. There are five vowels in Greek ([i, e, a, o, u]) and their spectral characteristics have been described in Fourakis et al. (1999). That study examined Greek vowels as produced by male speakers under different conditions of tempo, stress, finding significant effects of these factors on most acoustic characteristics (F0, amplitude, and formant structure). However, there have been no published results on vowels produced by women. In addition, there are no data on speech produced by Greek persons with cerebral palsy (henceforth CP), male or female. Thus, the present investigation presents production data (formant frequencies) for two groups of speakers – normal and CP, and perception data (classification of the productions by persons with normal hearing). Recent results on this area are reported by Liu et al. (2005) for Mandarin Chinese.

Experimental methodology

The subjects were six persons with CP and six with no known pathologies. There were three female and three male speakers in each group. All speakers used standard Athenian Greek pronunciation. Table 1 lists the characteristics of the subjects with CP.

Table 1. Personal index of the six speakers with cerebral palsy dysfunction.

Subject	Gender	Age	Education	Classification	Severity	Mobility
1	Female	27	BA	Spastic quadriplegic	Moderate to severe	Crutches
2	Female	26	BA	Dystonic quadriplegic	Severe	Wheelchair
3	Female	18	University freshman	Spastic paraplegic	Moderate to severe	Crutches
4	Male	35	High School	Hypotonic quadriplegic	Moderate To severe	Wheelchair
5	Male	23	Technical School	Spastic quadriplegic	Severe	Wheelchair
6	Male	30	BA	Spastic paraplegic	Moderate To severe	Crutches

The stimuli were nonsense CV_1CV_2 words where V_1 was one of the five Greek vowels [i, e, a, o, u], both consonants were always [s] and V_2 was always [a]. The words were presented in the carrier phrase “to kláb sV₁sa pézi kalí musikí” (The club sV₁sa plays good music). These words were produced five times by each speaker with stress either on V_1 or V_2 and at a normal rate of speech and recorded directly to disk at 44100 Hz sampling rate and 16 bit resolution. The center frequencies of the first and second formants (F1 and F2) were measured from LPC derived spectra. The LPC used a 20 ms window and the number of coefficients was adjusted for each speaker to yield good peak separation. In the perception part of the study, twelve persons with normal hearing listened to all tokens and classified them as one of the five vowels.

Results

Spectral characteristics

Figure 1 shows the vowel spaces produced by normal male and female speakers. The thick lines connect vowel means for the stressed conditions while the thin lines connect means for the unstressed condition. The relative

locations of the three point vowels are also indicated. The vowel spaces for the male speakers are in the lower F1 and F2 frequencies while those for the female speakers are in the higher frequencies. The introduction of stress results in a shrinkage of the vowel space which is more pronounced for the female speakers. However, the five vowels remain well separated in the respective vowel spaces.

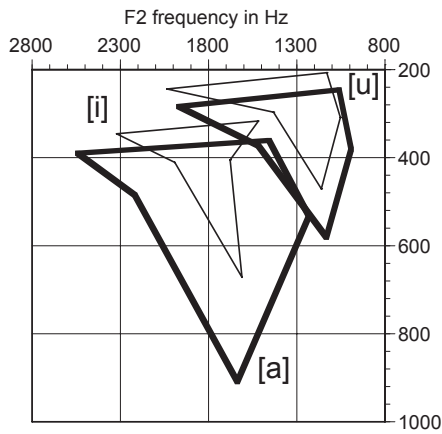


Figure1. Vowel spaces for normal male and female speakers.

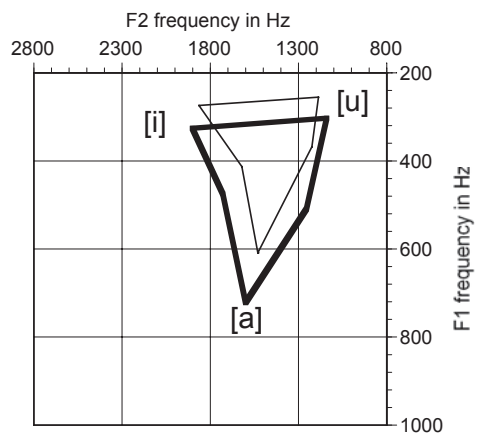


Figure2. Vowel spaces for male CP speakers.

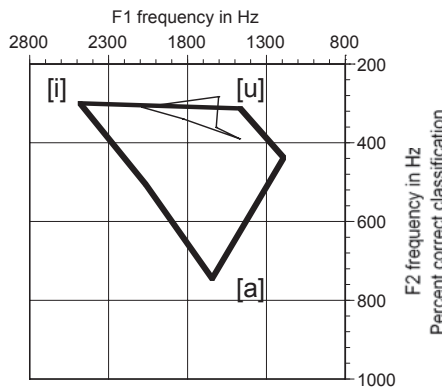


Figure 3. Vowel spaces for CP female speakers.

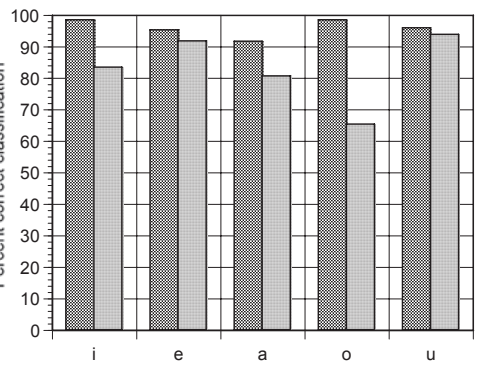


Figure 4. Classification of unstressed vowels produced by CP speakers.

Figures 2 and 3 show the stressed (thick lines) and unstressed (thin lines) vowel spaces for the male (Fig. 2) and female (Fig. 3) CP speakers. It can be seen that there is some vowel space reduction for the male CP speakers when unstressed vowels are compared to stressed ones. However, there is much more reduction for the female speakers which results (cf. discussion of Fig.4 below) in lower classification scores.

In the vowel identification experiment, the listeners with normal hearing classified vowels produced by the normal speakers with 99.7% accuracy. They classified stressed vowels produced by male CP speakers with 97.1% accuracy and female CP speakers with 99.7% accuracy. Figure 4 shows the results for unstressed vowels produced by male (checkered columns) and female (gray columns) CP speakers. Overall, vowels produced by male CP speakers were classified with 92.9 % accuracy while those produced by female CP speakers were classified with 82.6% accuracy. As can be seen in Fig.4, the vowels most affected were [i], [a], and [o] produced by the female CP speakers. Overall classification accuracy remained high, probably because of the fact that there were only five response choices and, as can be seen in Figure 3, despite the severe reduction of the unstressed vowel space, the five vowels remained well separated in the F1 by F2 acoustic space.

Discussion

The results presented here represent a first look at the effects of cerebral palsy on vowel production in speakers of Greek. In addition, acoustic and perceptual data for female Greek speakers are presented for the first time. The reduction of the unstressed vowel space relative to the stressed vowel one is much more pronounced for the female speakers than the male speakers regardless of mobility. Thus, in the CP female unstressed vowel space, which is the most reduced, there seems to be a combined effect of gender and mobility. This results in a 20% loss of intelligibility. In further research the effects on consonantal segment and whole word intelligibility will be examined using both male and female CP speakers as well as normal speakers for comparison.

References

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