

Vowel durations of normal and pathological speech

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Abstract

This is an experimental investigation of vowel durations in Greek, produced by normal speakers as well as speakers with cerebral palsy mobility dysfunction. The results indicate that mobility, gender and stress have significant effects on vowel durations. There are also significant interactions between mobility and stress as well as between gender and stress but not between mobility and gender.

Introduction

This is an experimental investigation of vowel durations in Greek as a function of mobility, gender, stress and vowel category. Two main questions are addressed: (1) what are the effects of the investigated factors? And (2) what are the interactions between the factors?

Considerable research has been carried out on Greek and contrastive prosody with regards to temporal structures and vowel durations (see e.g. Fourakis, 1986, Botinis, 1989). Thus, different vowels have different intrinsic durations, according to which low vowels are longer than high vowels and back vowels tend to be longer than front vowels (Fourakis et al., 1999). Stress has a temporal effect on vowels, according to which stressed vowels are longer than unstressed vowels (Botinis, 1989, Botinis et al., 2001, 2002). Gender has also a temporal effect on vowels and thus vowels produced by female speakers are longer than vowels produced by male speakers. The effect of gender is a language-specific effect as it has been reported for some languages, such as Greek and Albanian, but not for others, such as English and Ukrainian (Botinis et al., 2003).

Our knowledge with regards to pathological speech and cerebral palsy mobility dysfunction is very limited and the main target thus of the present investigation is to produce basic data and initialize research on speech produced by speakers with various pathologies.

Experimental methodology

The speech material under investigation consists of disyllabic nonsense words in the context of a meaningful carrier phrase. The words have a CVCV segmental structure where the first vowel (V) is one of the five Greek vowels, i.e. {i, e, a, o, u} in the carrier phrase “to kláb sVsa pézi kalí musikí” (The club sVsa plays good music). The nonsense key words were produced with lexical stress either on the first or second syllable and the speech material was produced in normal tempo with no prosodic brake on an individual basis.

The speakers were six persons with cerebral palsy dysfunction and six persons with no known pathologies (henceforth called the “mobility factor”) with standard Athenian Greek pronunciation. Each group was comprised of three female and three male speakers.

Acoustic analysis was carried out with the use of Wavesurfer and measurements were made of the vowel durations from the waveform. The results were subjected to statistical analysis with the StatView software package and ANOVA tests were carried out.

In the remainder of this paper, the results are presented next, followed by discussion and conclusions.

Results

The results are presented in Figures 1-6, based on the acoustic analysis and duration measurements of the total speech material in accordance with the experimental methodology.

Figure 1 (next page) shows overall vowel durations as a function of mobility and gender. Vowels produced by speakers with cerebral palsy were significantly longer than vowels produced by speakers with no pathologies ($F(1,596)=40.08$, $p<.001$). Vowels produced by female speakers were longer than vowels produced by male speakers ($F(1,596)=14.18$, $p<.001$). The interaction was not significant.

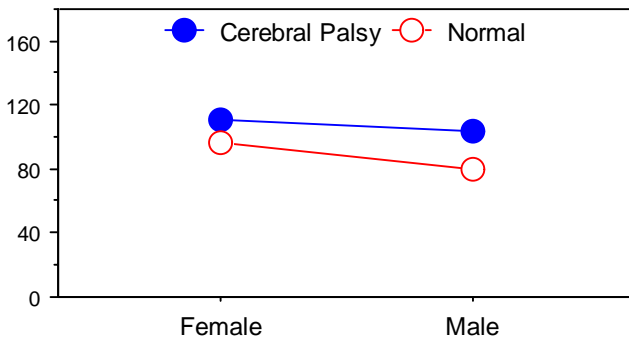


Figure 1. Overall vowel durations (ms) as a function of mobility and gender.

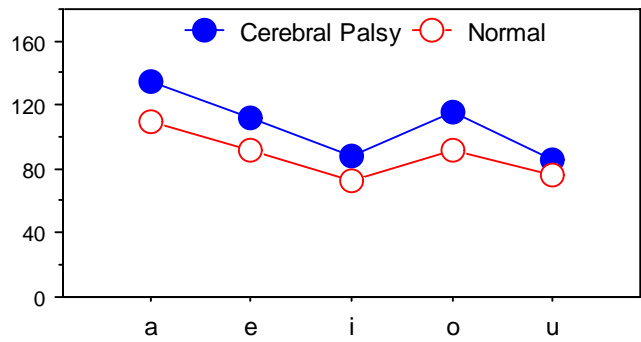


Figure 4. Individual vowel durations (ms) as a function of mobility.

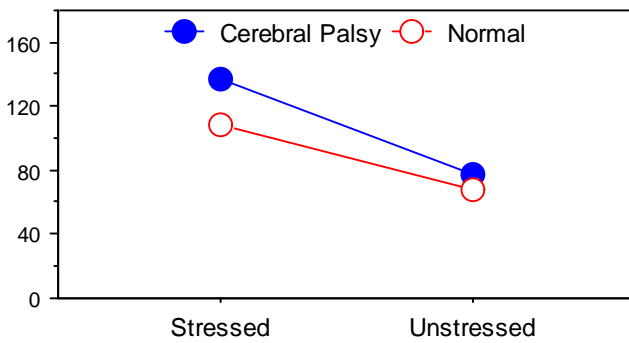


Figure 2. Overall vowel durations (ms) as a function of mobility and stress.

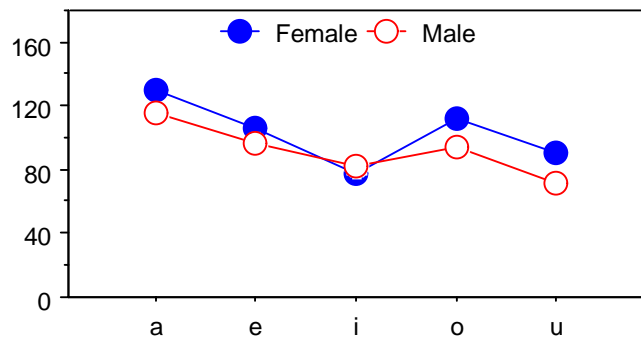


Figure 5. Individual vowel durations (ms) as a function of gender.



Figure 3. Overall vowel durations (ms) as a function of gender and stress.

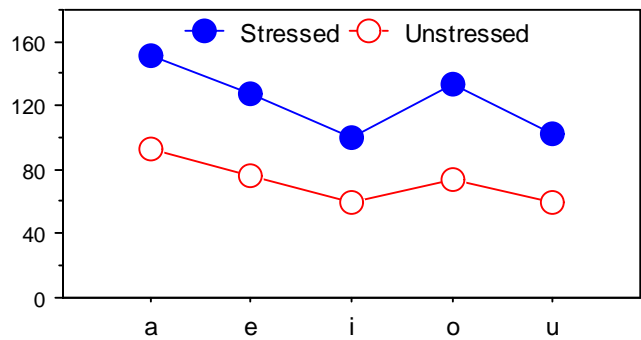


Figure 6. Individual vowel durations (ms) as a function of stress.

Figure 2 shows overall vowel durations as a function of mobility and stress. As before, vowels produced by persons with cerebral palsy were significantly longer than vowels produced by persons with no pathologies. Stressed vowels were longer than unstressed vowels ($F(1,596)=527, p<.001$). However, the interaction was significant ($F(1,596)=19, p<.001$). The difference between the two groups of speakers was greater for the stressed vowels than for the unstressed vowels. Post hoc t-tests revealed that the differences between groups

were significant for both stressed and unstressed vowels.

Figure 3 shows overall vowel durations as a function of gender and stress. As before, vowels produced by female speakers were longer than those produced by male speakers and stressed vowels were longer than unstressed vowels. However, the interaction was significant ($F(1,596)=43, p<.001$). Post hoc t-tests revealed that the difference was significant for stressed vowels ($t(298)=6.714, p<.001$) but not for unstressed vowels ($t(298)=-1.574, p>.05$).

The next set of comparisons examined individual vowel durations, in order to determine whether the three factors (mobility, gender, stress) affected all vowels uniformly or differently for each vowel.

Figure 4 (previous page) shows individual vowel durations for each speaker group. As before, vowels produced by speakers with cerebral palsy were longer than vowels produced by speakers with no pathologies. In addition vowel category also significantly affected vowel duration ($F(1,590)=33.56$, $p<.001$). However, there is no significant interaction ($F(4,590)=1.0$, $p>.05$). Thus, the effect of group was uniform for all vowels.

Figure 5 (previous page) shows individual vowel durations for each gender. As before, vowels produced by female speakers were longer than vowels produced by male speakers. Vowel category also significantly affected vowel duration ($F(1,590)=33.56$, $p<.001$). However, there was no significant interaction ($F(4,590)=2.364$, $p>.05$). Even though the analysis of variance did not produce a significant interaction (due to large variances), it is evident from the figure that the vowel [i] was longer for male speakers than for female speakers.

Figure 6 (previous page) shows individual vowel durations for each stress condition. As before, stressed vowels were longer than unstressed vowels. In addition vowel category also significantly affected vowel duration ($F(1,590)=66.44$, $p<.001$). The interaction was also significant ($F(4,590)=3.768$, $p<.01$). The effect is due to the different behavior of high [i, u] versus nonhigh [e, o, a]. High stressed vowels were on the average 42 ms longer than their unstressed counterparts while nonhigh stressed vowels were on the average 56 ms longer than their unstressed counterparts.

Discussion

In the present investigation, some old knowledge has been corroborated and some new knowledge has been produced. The old knowledge concerns the vowel category durations as well as the effects of stress and gender on vowel durations and the new knowledge concerns the effects of cerebral palsy dysfunction on vowel durations.

Our results indicate that the investigated factors of mobility, gender and stress have a significant effect on vowel durations, i.e. vowels

produced by speakers with cerebral palsy dysfunction are longer than vowels produced by normal speakers, vowels produced by female speakers are longer than vowels produced by male speakers, and stressed vowels are longer than unstressed vowels. There were also significant interactions between mobility and stress as well as gender and stress, i.e. both mobility and gender temporal effects are mostly correlated to stressed syllables and have hardly any effect on unstressed syllables. Furthermore, the five Greek vowels have different intrinsic durations, which are mainly determined by the low vs. high dimension, i.e. low vowels are significantly longer than mid vowels which, in turn, are significantly longer than high vowels.

The intrinsic vowel durations, also referred to as "microprosody", are widely documented in the phonetics literature and reported in many languages, among them in Greek (Di Cristo and Hirst, 1986, Fourakis et al., 1999), and the present investigation corroborates earlier reports on this area.

The prosodic correlates of lexical stress have also been studied extensively and the results indicate that, other phonetic contexts being equal, stressed syllables and hence vowels are most usually longer than unstressed syllables in a variety of related as well as unrelated languages (Beckman, 1986, Botinis, 1989, Sluijter, 1995, Fant et al., 1991, 2000, Botinis et al., 2002, de Jong, 2004). Duration has been reported as an invariable acoustic correlate, which also functions as a perceptual correlate of lexical stress distinctions in Greek (Botinis, 1989, Botinis et al., 1999). Lexical stress has variable effects on consonants and vowels in different languages. In some languages the effects of lexical stress are larger on vowels than on consonants, whereas, in other languages, the effects of lexical stress are more equally distributed on vowels and consonants (Botinis, 2003). The effects of lexical stress in Greek are larger than other prosodic effects such as focus and syllable position (Botinis et al., 2002).

The effects of gender on segmental durations have not drawn particular attention in prosodic research and thus very little is known on this area. In the present investigation, experimental evidence has been provided that female speakers produce vowels with longer durations than that of male speakers. This is most probably a sociolinguistic effect as in Albanian and Greek, e.g., female vowel productions have longer durations than male vowel productions

whereas in other languages, such as English and Ukrainian, no gender effects on segmental durations have been observed. However, the effects of gender on vowel durations are mostly evident on vowels of stressed syllables and not on vowels of unstressed syllables.

The most important finding and the main target of the present investigation concerns the mobility factor and the effects of cerebral palsy dysfunction on vowel durations. Obviously, cerebral palsy has a lengthening effect on vowel durations, which is however confined to the stressed syllables. Thus, cerebral palsy speakers have satisfactory temporal control with reference to vowel durations of unstressed syllables which implies that cerebral palsy temporal effects are not evident in general speech production but are rather confined to several prosodic and phonetic categories. The results of the present investigation provide a starting point for research in this area and further work is required before the temporal structure of speech produced by persons with cerebral palsy is basically understood.

Beyond the present results, this investigation has led to further immediate questions with reference to consonant and vowel productions. Thus, on the one hand the effects of mobility on consonant durations and, on the other hand, the effects of mobility on quality and the formant structure of vowel productions are eminent questions to be dealt with in the framework of the present investigation.

Conclusions

In accordance with the results of the present investigation the following conclusions have been drawn: First, each mobility factor, gender factor and stress factor has a significant effect on vowel durations. Second there are significant interactions between mobility and lexical stress as well as between gender and lexical stress but not between mobility and gender. Thus, both mobility factor and gender factor have considerably bigger effects on stressed syllables than unstressed ones.

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