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PHONETIC VOWEL REDUCTION IN STANDARD MODERN GREEK

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ABSTRACT

This study examined phonetic vowel reduction in Standard Modern Greek by comparing the spectral and temporal characteristics of the five Greek vowels spoken by the same speakers in two speaking styles, namely conversational and read speech. Frequencies of the first two formants (F1 and F2) and duration were measured and the Euclidean distance from the centroid of the vowel space was computed for each vowel. Results showed extensive vowel reduction and variability in conversational speech compared to read speech. Across speaking styles, unstressed vowels were shorter and closer to the centre of the vowel space than stressed ones.

Keywords: Greek, phonetic vowel reduction, conversational speech

1. Introduction

Phonetic vowel reduction is a process whereby an intended vowel target is not reached. Reduced vowels are shorter and occupy a more central position in the vowel space compared to non-reduced ones. This gradient subphonemic process, often referred to as vowel undershoot, should not be confused with phonological vowel reduction, an obligatory, categorical substitution of sounds whereby vowel quality distinctions are neutralized in unstressed syllables (e.g. English *photographic* /fəʊtə'græfɪk/ vs. *photography* /fə'tɒgrəfi/). This study provides an in depth examination of phonetic vowel reduction in Greek by investigating the effect of speaking style and stress on the spectral and temporal characteristics of Greek vowels.

Factors that have been found to contribute to phonetic vowel reduction include *rate of speech* (Lindblom, 1963), *stress* (Delattre, 1969), *context* (Lindblom, 1963; Moon & Lindblom, 1994) and *speaking style* (Koopmans-Van Beinum, 1980; Moon & Lindblom, 1994). According to the Hyper-Hypo (H&H) theory (Lindblom, 1990), speech communication involves a balance between the speaker's attempt to minimize articulatory effort (i.e., speaker constraints) and the listener's need to understand what is said (listener constraints); depending on the communicative situation, speech production thus exhibits a wide range of variation along a continuum of hypo- (reduced) to hyper- (non-reduced) speech. Speakers are free to hypo-articulate in ideal listening conditions (e.g. quiet environments) but tend to hyper-articulate in adverse listening conditions (e.g. background noise) or when they think the listener might have difficulty understanding their speech (e.g. when addressing a person with a hearing loss, a child or a non-native speaker).

Despite acknowledging style-induced modifications in the speech signal, most research on vowels has examined CVC syllables, word lists, or short utterances that are read aloud under well-controlled conditions ('laboratory speech'). This choice is motivated by the fact that the use of laboratory speech allows designing and conducting controlled experiments. However, since laboratory speech differs in a highly systematic way from the type of speech speakers use in their everyday life, it remains questionable whether laboratory speech findings can generalize to conversational, spontaneous speech.

Relatively few studies have examined phonetic vowel reduction in conversational speech (Koopmans-Van Beinum, 1980 for Dutch; Deterding, 1997 for English; Harmegnies & Poch-Olivé, 1992 for Spanish), demonstrating shorter vowel durations and 'shrinkage' of the vowel space in conversational speech compared to read speech. Limited research is also available on the acoustic characteristics of Greek vowels. According to Dauer (1980), only high vowels reduce in Greek while unstressed vowels do not change in quality. However, this finding is not confirmed by more recent studies that have begun to explore phonetic vowel reduction in Greek (Baltazani 2006, 2007; Fourakis

et al., 1999) using read speech materials. These studies show an overall reduction of the vowel space in Greek unstressed syllables compared to stressed ones. Nicolaidis (2003) was the first to examine the acoustic characteristics of Greek vowels in spontaneous speech using monologues produced by two Greek male speakers. Her results show extensive variability and overlapping formant distributions especially in the centre of vowel space, resulting in less distinct vowels than previously reported in the Greek literature. The current study extends Nicolaidis' (2003) study in two ways: first, by examining a larger number of speakers and consequently a larger number of vowel tokens and, second, by comparing the spectral and temporal characteristics of Greek vowels in two speaking styles, namely conversational and read speech. The conversational speech materials were drawn from recordings of natural conversations between each participant and the author. Read versions of these conversations were recorded from the same speakers one week after the first recording. That way, identical materials in two speaking styles were elicited, spoken by the same speakers under the same recording conditions. The main goal of this study is therefore to examine the extent of phonetic vowel reduction in Greek, a language with a simple 5-vowel system which does not employ phonological vowel reduction.

2. Method

2.1 Participants

Eight native speakers of Standard Modern Greek, all post-graduate students at University College London, with a mean age of 24 years (range = 22-27 years) participated in the study. Participants reported no speech, language or hearing disorders and none had spent a period of more than one year in the UK at the time of the recordings. In order to avoid extensive variability due to anatomical differences between male and female speakers, only male speakers were recruited.

2.2 Recordings

Speech recordings took place in an anechoic chamber at the University College London with a sampling rate of 44.1 kHz, using a Sony 60ES DAT recorder with a B&K Sound Level Meter Type 2231 fitted with a 4165 microphone cartridge, placed at a distance of 50 cm from the speaker's mouth.

As already mentioned, conversational speech materials were drawn from recordings of natural conversations (semi-directed interviews) between each participant and the author. Each conversation lasted approximately ten minutes. The author chatted with each participant prior to the recording to make him feel relaxed. The conversations revolved around participants' hobbies, studies, etc. Based on speech naturalness and fluency, approximately five minutes were selected from each speaker to be further analyzed.

Conversations were transcribed orthographically by the author after removing repetitions and pauses and the orthographic versions were recorded from the same speakers one week after the first recording. Participants were instructed to read the paragraphs at a comfortable speaking rate as if they were asked to read aloud a passage in the classroom. They were also instructed to read the sentence again if they made a mistake when reading the materials. As a result, identical materials in two speaking styles were recorded by each participant. There was no way to perfectly control for prosodic context since it is impossible for speakers to reproduce the same intonation patterns.

Data were analyzed using the SFS speech analysis software (Huckvale, 2008). Vowels preceded or followed by other vowels were excluded from the analysis. Segmentation was made manually, taking the waveform and the wide-band spectrogram into consideration; each vowel was defined by the beginning and the end of its formant structure. Acoustic measurements of duration and first (F1) and second (F2) formant frequencies were made automatically using SFS scripts, then checked manually and corrected. In case of missing vowels in one speaking style (most commonly in conversational speech), the corresponding vowel in the other style was excluded from the analysis. For purposes of data presentation and statistical analyses, values in Hertz were converted to the auditory Bark scale. The formula proposed by Traunmüller (1990) and given in (1) was used, where Z is frequency in Bark and f is frequency in Hertz:

$$(1) \quad Z = \left[\frac{26.81f}{(1960 + f)} \right] - 0.53$$

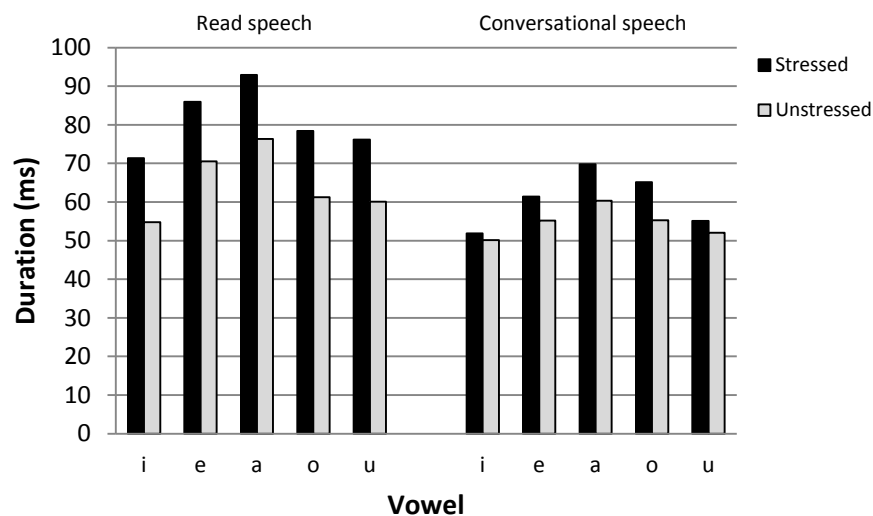


Figure 1 Mean duration (ms) of Greek vowels in read speech (left) and conversational speech (right) in both stress conditions

3. Results

3.1 Effects of speaking style and stress on vowel duration

Figure 1 shows the mean duration of each Greek vowel in read and conversational speech in both stress conditions. As can be seen, Greek vowels were shorter in conversational than in read speech. In addition, across speaking styles, unstressed vowels were shorter than stressed ones. Vowel durations were submitted to a three-way analysis of variance (ANOVA) with Speaking style (read, conversational), Stress (stressed, unstressed) and Vowel (5 levels) as factors. There was a significant main effect of Speaking style [$F(1,3460) = 58.253, p < 0.001$], confirming that Greek vowels were shorter in conversational speech than in read speech and a significant effect of stress [$F(1,3460) = 156.046, p < 0.001$] confirming that unstressed vowels were shorter than stressed ones. There was also a significant main effect of Vowel [$F(4,3460) = 26.946, p < 0.001$]. Pairwise comparisons (Bonferroni adjusted) showed that, across speaking styles and stress conditions, the low central vowel /a/ was produced with the longest duration, the high vowels /i/ and /u/ with the shortest durations and the mid vowels /e/ and /o/ were in between. Similar results are reported in the literature for Greek vowels (e.g. Baltazani, 2006; Fourakis et al. 1999; Nicolaidis, 2003) and other languages (for a review, see Lehiste, 1970). There was also a significant Speaking style \times Stress interaction [$F(1,3460) = 22.54, p < 0.001$], indicating that vowels in read speech were shortened to a larger degree when unstressed than vowels in conversational speech (25% vs. 15% respectively). Finally, a significant Vowel \times Stress interaction [$F(4,3460) = 7.54, p < 0.01$] indicated that not all vowels were shortened to the same degree when unstressed; /a/ was shortened to a larger degree than the mid vowels /e/ and /o/ and the high vowels /i/ and /u/. Mean durations and standard deviations for the five Greek vowels in two speaking styles in both stress conditions are given in Table 1. Focusing on conversational speech materials, vowel durations were found to be somewhat shorter than those reported in Nicolaidis (2003) who provides the following duration values (pooled over stressed and unstressed conditions) for vowels in spontaneous speech): /i/ = 69.1 ms, /e/ = 80.9 ms, /a/ = 85.4 ms, /o/ = 78.4 ms and /u/ = 59.8 ms. One possible explanation is that speech in conversation examined in the current study is less careful and hence faster than speech in monologues examined in Nicolaidis' (2003) study.

Vowel	Read speech		Conversational speech	
	Stressed	Unstressed	Stressed	Unstressed
/i/	71.34 (23.77)	51.83 (17.86)	54.74 (22.76)	50.14 (23.64)
/e/	85.98 (27.48)	61.43 (23.63)	70.53 (22.51)	55.21 (21.64)
/a/	92.94 (29.25)	69.76 (22.63)	76.32 (25.62)	60.32 (19.33)
/o/	78.44 (20.54)	65.16 (18.42)	61.26 (19.24)	55.31 (17.89)
/u/	76.18 (22.94)	55.11 (13.55)	60.09 (10.43)	52.02 (16.65)

Table 1 Mean duration of Greek vowels (ms) and standard deviations in read and conversational speech in both stress conditions

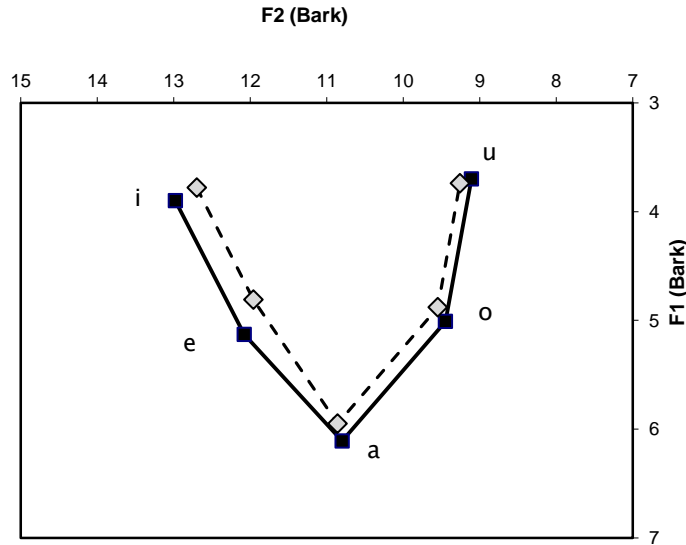


Figure 2 Mean F1 and F2 frequencies (Bark) of Greek vowels spoken in read speech in stressed (black squares) and unstressed position (grey diamonds)

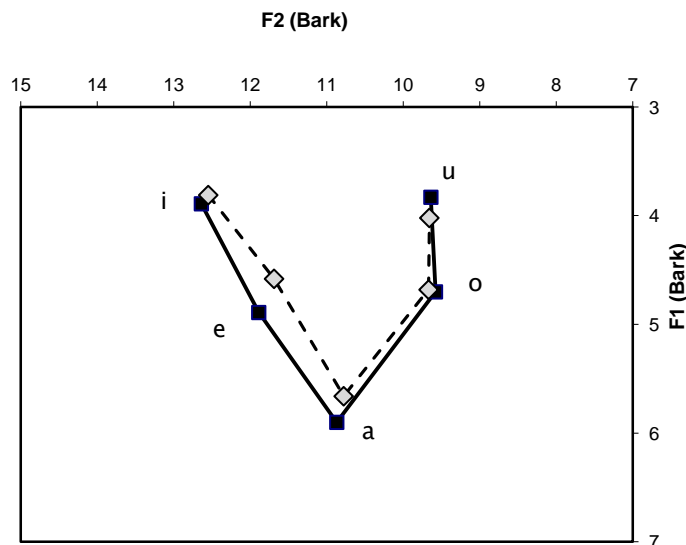


Figure 3 Mean F1 and F2 frequencies (Bark) of Greek vowels spoken in conversational speech in stressed (black squares) and unstressed position (grey diamonds)

3.2 Effects of speaking style and stress on formant frequencies

Mean F1 and F2 frequencies (converted to the Bark scale) of the five Greek vowels in read and conversational speech are plotted in the vowel space in Figures 2 and 3 respectively and are also given in Hz (standard deviations in parentheses) in Table 2. A visual inspection of Figures 2 and 3 reveals that Greek vowels in conversational speech show a tendency towards reduced vowel spaces (i.e., they occupy less peripheral positions) when compared to vowels in read speech. Moreover, across speaking styles, unstressed Greek vowels are reduced towards the centre of the vowel space compared to stressed ones. These results agree with Koopmans-Van Beinum (1980), Deterding (1997) and Harmegnies & Poch-Olivé (1992) who compared vowels in conversational and read speech. The results are also in agreement with Fourakis et al. (1999) and Baltazani (2006, 2007) who found a reduction of the Greek vowel space in unstressed position using read speech materials.

Vowel	Read speech				Conversational speech			
	Stressed		Unstressed		Stressed		Unstressed	
	F1	F2	F1	F2	F1	F2	F1	F2
/i/	385 (71)	1995 (86)	376 (82)	1918 (102)	385 (80)	1895 (97)	376 (86)	1872 (104)
/e/	522 (74)	1742 (82)	489 (96)	1715 (86)	492 (87)	1690 (91)	470 (89)	1643 (95)
/a/	644 (84)	1421 (81)	628 (104)	1450 (90)	609 (93)	1444 (92)	592 (109)	1432 (93)
/o/	502 (86)	1165 (103)	500 (101)	1190 (102)	470 (95)	1179 (112)	471 (102)	1208 (117)
/u/	362 (74)	1102 (118)	372 (83)	1126 (116)	376 (76)	1200 (124)	403 (114)	1206 (119)

Table 2 F1 and F2 frequencies in Hz (standard deviations in parentheses) of Greek vowels in read and conversational speech in both stress conditions

To test these observations statistically, the Euclidean distance for each vowel token was calculated from the *centroid*¹ of each speaker's vowel space. The formula given in (2) was used, where $\overline{F1}$ is the mean of each speaker's F1 values and $\overline{F2}$ is the mean of each speaker's F2 values. The smaller the Euclidean distance, the more centralized a vowel token is.

$$(2) \quad ed = \sqrt{(F1 - \overline{F1})^2 + (F2 - \overline{F2})^2}$$

Table 3 displays the mean Euclidean distance of the five Greek vowels in read and conversational speech in both stress conditions. Euclidean distances were submitted to a three-way ANOVA with Speaking style (read, conversational), Stress (stressed, unstressed) and Vowel (5 levels) as factors. The ANOVA yielded three main effects: of Speaking style [$F(1,3460) = 19.543, p < 0.001$] with vowels in conversational speech being closer to the centroid, of Stress [$F(1,3460) = 9.434, p < 0.01$] with unstressed vowels being closer to the centroid and of Vowel [$F(4,3460) = 322.545, p < 0.001$]. These results confirmed a reduction of the vowel space not only in terms of quantity as shown in section 3.1 but also in terms of quality when moving from (a) conversational to read speech and (b) stressed to unstressed position.

A final point of interest concerns a comparison of variability in F1 and F2 frequencies in conversational and read speech. As can be seen in Table 2, standard deviations of F1 and F2 were consistently larger in conversational speech compared to read speech which, combined with the centralization of F1 and F2 values found in the data, results in less differentiated vowels in conversational speech than in read speech (see Nicolaidis, 2003 for a similar finding concerning Greek vowels in spontaneous speech).

¹ The *centroid* of the vowel space is the grand mean of all formant measurements taken for each speaker.

Vowel	Read speech		Conversational speech	
	Stressed	Unstressed	Stressed	Unstressed
/i/	2.13 (0.53)	2.04 (0.61)	1.91 (0.57)	1.90 (0.61)
/e/	1.09 (0.51)	1.06 (0.57)	1.05 (0.52)	0.97 (0.57)
/a/	1.34 (0.52)	1.23 (0.60)	1.22 (0.58)	1.19 (0.60)
/o/	1.81 (0.73)	1.73 (0.71)	1.82 (0.78)	1.73 (0.79)
/u/	2.62 (1.05)	2.35 (0.85)	2.24 (0.98)	2.10 (0.89)

Table 3 Euclidean distance (Bark) for Greek vowels in read and conversational speech in both stress conditions (standard deviations in parentheses)

4. Discussion

This study examined the spectral and temporal characteristics of Greek vowels in two speaking styles in stressed and unstressed position with the aims of (a) adding to our existing knowledge on the acoustic characteristics of Greek vowels and (b) revealing style-induced differences. The styles under investigation were conversational and read speech (the read version of conversational speech materials). If we consider speaking style as a continuum where conversational speech stands at one end of the continuum and isolated syllables (or words) at the other, the speaking styles to be compared are relatively close to each other. Nonetheless, it was hypothesized that significant differences between these speaking styles in terms of duration, formant frequencies and Euclidean distance of the centroid of the vowel space would be found.

As far as duration is concerned, vowels in conversational speech were significantly shorter compared to vowels in read speech in both stress conditions. In addition, stressed vowels were longer than unstressed ones across speaking styles. Finally, the results confirmed the well-documented phenomenon of low vowels being inherently longer than high vowels (e.g. Lehiste, 1970); across speaking styles and stress conditions, the open central vowel /a/ was found to be the longest vowel, followed by the mid vowels /e/ and /o/, which were in turn followed by the high vowels /i/ and /u/.

In order to test whether vowel space reduced in conversational speech, the Euclidean distance for each vowel token was calculated from the centroid of the vowel space. Vowels in conversational speech were found to occupy a more central position in the vowel space than vowels in read speech with unstressed vowels being closer to the centroid in both speaking styles (Koopmans-Van Beinum, 1980; Deterding, 1997; Harmegnies & Poch-Olivé, 1992). These findings are in agreement with the target-undershoot model (Lindblom, 1963; Moon & Lindblom, 1994) and the H&H theory (Lindblom, 1990). Within this framework, speech production depends on the communicative situation and can vary along a hyper- to hypo- continuum. As previously mentioned, the conversational speech materials for this study were elicited in a sound isolated chamber that ensured ideal speaking and listening conditions. The conversation between the participants and the author was fairly friendly and informal. In this experimental setting, speakers are expected to produce reduced speech in order to economize articulatory effort. The read speech materials for the study were elicited under the same recording conditions. However, the participants read a passage instead of conversing freely and were instructed to read the way they would read aloud a passage in the classroom if the teacher asked them to. In this experimental setting, conversely, speakers are expected to produce less reduced vowels, closer in acoustic quality and quantity to the target values. It is important to mention that vowels in read speech in this study were found to be less peripheral when compared to formant values given for Greek vowels spoken in isolated sentences (e.g. Baltazani, 2006; Fourakis et al., 1999), indicating that these vowels were reduced too but to a lesser degree than vowels in conversational speech. Future research could compare vowels in three speaking styles, namely conversational speech, continuous read speech and words isolated or embedded in a carrier sentence. It would also be interesting to test Greek native speakers' perception (e.g. vowel identification and goodness ratings) of Greek vowels spoken in conversational speech when context (i.e., lexical information) is removed.

In summary, the results of this study provide strong evidence for the existence of phonetic vowel reduction in Greek and demonstrate two ways in which vowels in conversational speech differ from vowels in read speech; conversational speech vowels are shorter in duration and less peripheral in the F1 × F2 vowel space. These findings add to the existing evidence in the literature that read speech (used commonly in speech production experiments) differs in a highly systematic way from the type of speech used in our everyday communication.

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