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The Nature of Phonetic Gradience across a Dialect Continuum: Evidence from Modern Greek Vowels

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Abstract

This study investigates the acoustic properties of vowels in 2 Modern Greek varieties: Standard Modern Greek (SMG) and Cypriot Greek (CG). Both varieties contain in their phonetic inventories the same 5 vowels. Forty-five female speakers between 19 and 29 years old participated in this study: 20 SMG speakers and 25 CG speakers, born and raised in Athens and Nicosia, respectively. Stimuli consisted of a set of nonsense CVCV and VCV words, each containing 1 of the 5 Greek vowels in stressed and unstressed position. Gaining insights from the controlled experimental design, the study sheds light on the gradient effects of vowel variation in Modern Greek. It shows that (1) stressed vowels are more peripheral than unstressed vowels, (2) SMG unstressed /i a u/ vowels are more raised than the corresponding CG vowels, (3) SMG unstressed vowels are shorter than CG unstressed vowels, and (4) SMG /i o u/ are more rounded than the corresponding CG vowels. Moreover, it shows that variation applies to specific subsystems, as it is the unstressed vowels that vary cross-varietally whereas the stressed vowels display only minor differences. The implications of these findings with respect to vowel raising and vowel reduction are discussed.

1 Introduction

The Modern Greek vowel system consists of 5 vowels: the high vowels /i/ and /u/, the non-high and non-low vowels /e/ and /o/, and the low vowel /a/ (Fig. 1). From these vowels, /u/ and /o/ are back vowels and /i/ and /e/ are front vowels. /u/ and /o/ are more rounded than /i/ and /e/ (Householder et al., 1964; Trudgill, 2009).

Trudgill (2009) notes that the vowel system of Modern Greek is strikingly ordinary and almost predictable. Nevertheless, when regional variation is brought into account, an enormous complexity is unveiled under the elegant simplicity of this 5-vowel system. In the beginning of the previous century, Georgios Chatzidakis, an

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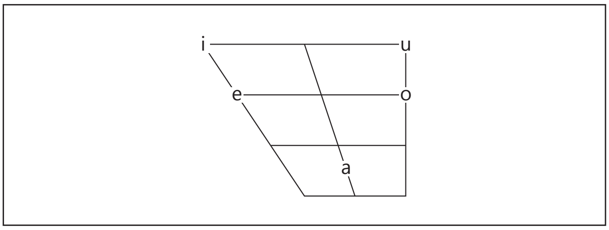

Fig. 1. Modern Greek Vowels.

eminent historical linguist and dialectologist, observed that Greek varieties differ with respect to their vowels (Chatzidakis, 1905, 250–265) and divided Greek varieties into two major groups: the northern and the southern varieties. He also set the 38th parallel as the dividing line between these dialect areas (Chatzidakis, 1905, pp. 250–265). The northern varieties raise unstressed mid vowels and delete high vowels – a phenomenon known in Greek dialectology as vowel raising and high vowel deletion (Chatzidakis, 1905, pp. 250–265). Also, the unstressed vowels are characterized by vowel reduction, that is, the unstressed vowels become more central and shorter than the stressed vowels (e.g., Kontosopoulos, 1981, 2011; Newton, 1972b; Dauer, 1980; Trudgill, 2003). Similarly, in English, unstressed vowels can be manifested as a schwa or a syllabic consonant (e.g., puddle /ˈpʌdəl/ or /ˈpʌdl̩/, golden /ˈɡəʊldən/ or /ˈɡəʊldn̩/).

Notably, others observed that there might be exceptions to this classification; as Newton (1972b, p. 182) notes "it is by no means the case that all unstressed high vowels are deleted and all unstressed mid vowels raised in northern Greek dialects." Therefore, they provided finer dialectal classifications (e.g., Kontosopoulos, 1981, 2011; Newton, 1972b; Trudgill, 2003). For instance, Kontosopoulos (1981) classified the northern varieties into *Strict Northern Varieties*, *Nonstrict Northern Varieties*, and *Seminorthern Varieties*. *Strict Northern Varieties* are those that raise unstressed /e/ and /o/ to /i/ and /u/, respectively, and delete unstressed /i/ and /u/ in medial and word-final position. *Nonstrict Northern Varieties* are those that delete /i/ and /u/ in word-final position. *Seminorthern Varieties* are those that delete unstressed word-final /i/, and often unstressed word-medial /i/ and /u/ without raising /e/ and /o/ (see also the discussion in Newton, 1972a, b; Kontosopoulos, 1988, 2011; Trudgill, 2003).

The southern varieties of Modern Greek, by contrast, such as the Standard Modern Greek (SMG) and the Cypriot Greek (CG) are not characterized by vowel raising and reduction (e.g., Chatzidakis, 1905; Newton, 1972a, b; Kontosopoulos, 1988, 2011). Yet, a number of studies cast doubt on this classification, by suggesting that even the southern varieties may vary with respect to vowel raising and vowel reduction. For instance, based on evidence from diachronic change in CG, Menardos (1894) suggested that vowel reduction and deletion can take place in CG more often than in SMG. What is more, Loukina (2011) provides acoustic evidence from spontaneous monologues produced by speakers from Athens, Thessaly (Karditsa), and Cyprus (Nicosia) between 75 and 93 years old, which show that vowel reduction might pertain to both SMG and CG. Specifically, she found evidence of vowel raising in all speakers but the effects of raising were stronger for the speakers from Thessaly > Athens > Cyprus. Note that, because the speakers in her study had been living in Athens for more than 60 years, it is highly possible that their speech was influenced by SMG, so their vowels may not be representative of CG and Thessalian Greek vowels (e.g. see Siegel, 2010, for a review of studies that discuss the interlanguage of bidialectal speakers).

SMG and CG are geographically distinct but previous studies group them together as southern varieties with respect to their vowels (see for instance Chatzidakis, 1905; Newton, 1972b), whereas other studies provide evidence of vowel variation, which suggests that they should not be grouped together (Menardos, 1894; Dauer, 1980). However, there are no previous acoustic studies of CG vowels and comparative studies of SMG and CG vowels (however, for some preliminary results of this research, see here Themistocleous and Logotheti, 2016), thus all the preceding claims rely primarily on impressionistic evidence (see however Loukina, 2011).

2 This Study

This study compares the SMG and CG vowels in an attempt (1) to shed light on vowel variation in Modern Greek, (2) to investigate whether vowel raising and vowel reduction take place within southern varieties, and (3) to provide a reference point for further research on language variation and language change in Greek. To this purpose, the study explores the effects of language variety, vowel quality, and stress on the F1, F2, F3, F0, and duration. The selection of these acoustic properties has been motivated by the following hypotheses:

The position of the vowels in the vowel space: the null hypothesis predicts that the 2 varieties do not differ in the F1 × F2 vowel area. The F1 determines the height dimension, and the F2 determines the frontness-backness dimension of vowels (e.g., Fox and Jacewicz, 2009; Harrington, 2010). The alternative hypothesis is that there are differences in the vowel space area. If the alternative hypothesis is corrected as studies from English and other languages suggest (e.g., Labov, 1994; Labov et al., 2006; Boberg, 2008; Gross et al., 2016), we expect significant effects of the variety on the F1 and F2.

Dialectal variation in the F3 and differences in vowel rounding: the null hypothesis is that the 2 varieties do not differ in the F3. The alternative hypothesis is that the variety has significant effects on the F3. Earlier research showed that the F3 varies cross-varietally, e.g. the F3 is lowered in the "r-colored" varieties of American English (see also Eklund and Traunmüller, 1997; Jongman et al., 1989; O'Brien and Smith, 2010; Chung et al., 2012), which points to possible effects of variety on the F3 (Harrington, 2010). Although the F3 is less understood than the F1 and F2 (see Adank et al., 2004; Leinonen, 2010), a number of studies show that the segmental context can have significant effects on the F3 (Harrington, 2010), and in languages with round vowels, such as in Swedish, the F3 can distinguish the rounded vowels from the nonrounded ones (Fujimura, 1967). To examine whether the SMG and CG vowels differ with respect to rounding, this study controls the segmental environment of vowels.

Dialectal variation in the vowel duration and F0: the null hypothesis is that there are no effects of the language variety on the duration and the F0. The alternative hypothesis is that there are effects of the language variety on the duration and F0. Overall, the reduction of unstressed vowels influences the vowel quality, which is reflected in effects on the vowel formants and the vowel duration. In SMG, unstressed vowels are shorter than stressed vowels (e.g., Fourakis et al., 1999). Moreover, prosodic boundaries, (post-)lexical prominence, and tunes have varying effects on vowel duration (e.g., for SMG, see Botinis, 1989; Arvaniti, 1991, 1994; Themistocleous, 2011; for CG, see Themistocleous, 2011, 2014). Other studies show the effects of the prosodic structure on vowel duration, such as accentual lengthening (e.g., Botinis, 1989; Arvaniti, 1991; Themistocleous, 2011) and final lengthening (e.g., Themistocleous, 2008, 2014). Earlier studies have shown that the SMG and CG differ with respect to the F0 and the duration of both consonants and vowels (e.g., Themistocleous, 2011); thus, they provide support for the alternative hypothesis.

SMG is spoken mainly by 11 million people in Greece and other Greeks who live elsewhere. CG is another Modern Greek variety spoken by 800,000 speakers in Cyprus (CYSTAT, 2011). The 2 varieties differ in their sociolinguistic history: SMG is the result of a long standardization procedure, which occurred from the dialectic between the more literary "pure" Greek (a.k.a., Katharevousa) and the vernacular of the time (a.k.a., Demotic Greek) whereas CG evolved as a nonstandardized variety. The 2 varieties differ in many aspects of their phonetics, phonology and morphosyntax (cf. Newton, 1972a; Rowe and Grohmann, 2013; Hadjioannou et al., 2011; Themistocleous, 2011). For instance, in CG there are postalveolar fricatives and affricates and the voiced stops are always prenasalized whereas in SMG there are no postalveolar consonants and the voiced stops can be nonprenasalized (Arvaniti and Joseph, 2004). Notably, CG contains in the phonemic inventory both geminates and singletons whereas this distinction does not exist in SMG (Eftychiou, 2009, 2010).

3 Methods

In this experimental study, we constructed a large corpus of recorded speech from 2 different urban centers: Athens and Nicosia, the capital cities of Greece and Cyprus, respectively. The variety spoken in Athens is SMG, and in Nicosia it is CG.

3.1 Speech Stimuli and Procedure

Forty-five female speakers between 19 and 29 years old participated in this study: 20 SMG speakers and 25 CG speakers, born and raised in Athens and Nicosia, respectively. A demographic questionnaire distributed to the participants verified that speakers originated from approximately the same socioeconomic background. All speakers were university students: CG speakers were students at the University of Cyprus, and SMG speakers were students at the University of Athens. The speakers were bilingual in Greek and English (as a second language). None reported a speech or hearing disorder. For the SMG material, the recordings were made in a recording studio in Athens, and for the CG material, the recordings were made in a quiet room at the University of Cyprus.

Stimuli consisted of a set of nonsense V̀*sa*, V*sà*, sV̀sa, and sVsà words, where V stands for an unstressed vowel and V̀ stands for a stressed vowel. Each word contains 1 of the 5 Greek vowels (/i e a o u/) in both stressed and unstressed position, word initially and word medially. To control the segmental environment, all vowels are preceded and followed by the alveolar sound /s/. Note that the selection of nonsense CVCV/VCV words has the advantage that it enables the experimental control of the segmental environment, before and after the vowel, and of the stress pattern (that is, word initial and word medial) (for other studies using nonsense CVCV words, see e.g., Öhman, 1966; Bouferroum and Boudraa, 2015). The carrier phrases differed slightly to address the different characteristics of each variety:

SMG: "/ˈipes < *keyword* > ˈpali/" (You said < *keyword* > again)
CG: "/ˈipes < *keyword* > ˈpale/" (You said < *keyword* > again).

To provide variation within the experimental material and to minimize the speaker's attention on the experimental words, nonsense ˈCVCV and CVˈCV words, consisting of different segments than

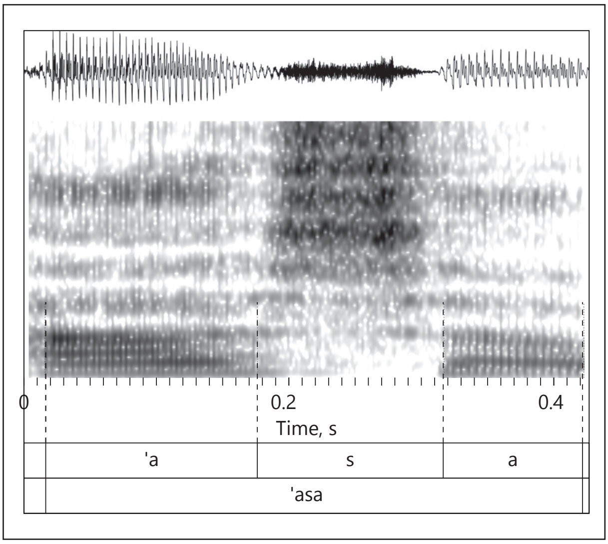

Fig. 2. Spectrogram and waveform of the keyword /ˈasa/ produced by a speaker of SMG.

the targeted keywords (e.g., ˈfasi, saˈki) were inserted in the same carrying phrases and randomized in the speech material. Each subject produced 80 utterances – without the fillers. The overall speech material consisted of 3,600 vowel productions (i.e., 45 speakers × 5 vowels × 2 stress conditions × 2 word positions × 4 repetitions).

The target words were presented in Greek orthography. The stimuli were randomized for each repetition and speaker. Between repetitions there was a 1-min break. SMG and CG speakers were recorded by an SMG-speaking and a CG-speaking research assistant, respectively. No instructions about the prosodic pattern or any explanation about the purposes of the experiment were provided. The speakers read sentences out loud from a computer screen, at a comfortable, self-selected rate. Recordings were made on a Zoom H4n audio recorder (sampling frequency 44.1 kHz). For the acoustic analysis, the open source software Praat 5.3.32 was used (Boersma and Weenink, 2014).

3.2 Acoustic Analysis and Measurements

Vowels were segmented as follows: vowel onsets and offsets were located manually by employing simultaneous inspections of the waveform and spectrogram, and the overall duration was calculated. Vowel onset was located at the zero crossing after the offset of the *s*-frication in the periodic waveform, and the vowel offset was defined by the onset of the following *s*-frication. In addition, the onset and the offset of the F1 – with respect to the preceding and following *s*-frication – were employed to set the left and right boundary of vowels, respectively. Figure 2 shows the waveform and the spectrogram of the vowel /a/ and the corresponding segmental boundaries of the segments that constitute the keyword [ˈasa]. The formant frequencies (i.e., F1, F2, and F3), and F0 were measured at the middle of the vowel (Joos, 1948; Jones, 1956). Praat's standard LPC-based method has been employed for the extraction of vowel formants.

Calculating Vowel Space Areas. The area formed by the 5 stressed and unstressed vowels of SMG and CG was calculated following the Gauss area formula (also known as shoelace formula). This formula determines the area of a simple polygon with known vertices – in this case, the vertices are the locations of vowels in the F1 × F2 plot; as the latter constitutes a 2-dimensional Euclidean space, the location of each vowel is defined by its (F2, F1) coordinates.

$$\mathbf{A} = \frac{1}{2}\left| \sum_{i=1}^{n-1} x_i y_{i+1} + x_n y_1 - \sum_{i=1}^{n-1} x_{i+1} y_i - x_1 y_n \right| \quad (1)$$

Table 1. Speech material

Vowels	Initial		Medial	
	Stressed	unstressed	stressed	Unstressed
/i/	ˈisa	iˈsa	ˈsisa	siˈsa
/e/	ˈesa	eˈsa	ˈsesa	seˈsa
/a/	ˈasa	aˈsa	ˈsasa	saˈsa
/o/	ˈosa	oˈsa	ˈsosa	soˈsa
/u/	ˈusa	uˈsa	ˈsusa	suˈsa

where (1) A is the vowel area, (2) n is the number of sides of the vowel polygon, which in this case is equal to 5, and (3) (x_i, y_i), i = 1, 2,..., n are the corners of the vowel polygon, e.g., (F2, F1) of one of the 5 vowels, which are designated with the index i.

In total, 788 sets of vowels, i.e. (197 stressed vowels + 197 unstressed vowels) × 2 varieties, were randomly selected from the database, and the corresponding vowel areas were calculated.

3.3 Statistics

To analyze the data, we employed linear mixed models for each one of the response variables (F1, F2, F3, F0, and duration). The fixed effects in the final model were *Vowel*, *Stress*, *Variety*, and their interactions. As random effects, random intercepts were modeled for *Speakers* and *Items* (for an account on linear mixed models, see Baayen, 2008a).

Linear mixed models take into account both fixed factors (i.e., experimental manipulations) and random factors (i.e., speakers and keywords); thus, they provide a coherent framework for statistical inference (see e.g., Baayen, 2008). To analyze the data, several models were compared starting with the 3 fixed factors and their interaction and maximal random effects. Then we employed the diagnostics for detecting overparameterization and model simplification (such as changes in the Akaike information criterion for each model) proposed in Bates et al. (2015). The final model selected is shown below:

$$RV \sim vowel \bullet stress \bullet variety + (1/speaker) + (1/keyword). \tag{2}$$

The statistical analysis was carried out in R (R Core Team, 2014). The lme4 is an R package providing the functions for fitting generalized linear mixed models (Bates et al., 2014).

$$area \sim variety \bullet stress. \tag{3}$$

For the vowel space area, a linear regression was performed with the area as the response variable and both the main effects and interactions of *stress* and *variety* (see Equation 3).

4 Results

Overall, *stress* has significant effects on vowel acoustic properties in both varieties. The stressed vowels are more peripheral and occupy greater vowel space than the unstressed vowels. The stressed vowels are also longer than the unstressed ones. Besides *stress*, *variety* has significant effects on vowel acoustic properties. The unstressed SMG /i/ and /u/ vowels are significantly higher than unstressed CG vowels. They are also shorter than the CG vowels. Next, the findings on the effects of *vowel*, *stress*, and *variety* on vowel formants, duration and F0 are presented in detail.

Table 2. Mean(and *SD*) of *F*1 and *F*2 in Hertz for stressed (S) and unstressed (U) SMG and CG vowels

		i		e		a		o		u	
var	str	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
		*F*1									
SMG	S	392	40	619	63	874	98	608	64	419	46
	U	370	208	483	69	692	132	485	106	373	151
CG	S	404	81	579	68	898	108	583	74	437	108
	U	386	62	503	69	773	120	504	102	397	54
		*F*2									
SMG	S	2422	251	2021	254	1582	149	1238	138	1185	248
	U	2321	203	2019	170	1670	147	1401	224	1499	298
CG	S	2604	366	2043	352	1613	230	1228	153	1171	380
	U	2484	364	2040	284	1657	199	1382	233	1454	396

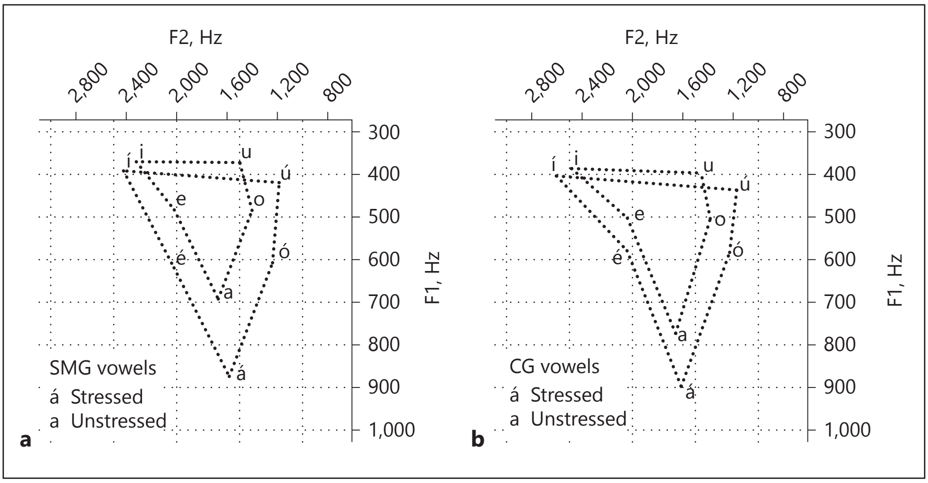

Fig. 3. SMG (left panel, **a**) and CG (right panel, **b**) vowel *F*1 × *F*2 by *Stress*.

4.1 F1 × F2

Table 2 reports the mean value and the standard deviation (SD) of F1 and F2 in SMG and CG stressed and unstressed vowels. The overall acoustic effects of *stress* and *variety* on vowels are displayed in the 2-dimensional acoustic space shown in Figure 3.

Unstressed vowels have lower F1 than stressed vowels, so they are more raised than their stressed counterparts. The area connected by the 5 average vowel points is greater for the stressed than for the unstressed vowels (Fig. 3). In the front back dimension, stressed vowels occupy more peripheral positions than the corresponding unstressed vowels. As a result, the vowel area of stressed vowels is greater than the vowel area of unstressed vowels. The SMG vowel areas for stressed (mean = 304 kHz^2, SD = 125 kHz^2) and unstressed (mean = 164 kHz^2, SD = 105 kHz^2) vowels are smaller

Table 3. Results of the Generalized Mixed Model for *F*1

Response: *F*1	Chisq	Df	Pr(> χ^2)
Vowel	1858	4	<0.0001
Stress	140.15	1	<0.0001
Variety	2.45	1	0.12
Vowel: Stress	50	4	<0.0001
Vowel: Variety	67	4	<0.0001
Stress: Variety	23	1	<0.0001
Vowel: Stress: Variety	39.0	4	<0.0001

Table 4. Results of the Linear Mixed Model for *F*2

Response: *F*2	Chisq	Df	Pr(> χ^2)
Vowel	1009.99	4	<0.0001
Stress	11.83	1	<0.001
Variety	0.4	1	0.6
Vowel: Stress	21.7	4	<0.001
Vowel: Variety	59.4	4	<0.0001
Stress: Variety	7	1	<0.01
Vowel: Stress: Variety	1.9	4	0.75

than the corresponding stressed (mean = 299 kHz^2, SD = 153 kHz^2) and unstressed (mean = 111 kHz^2, SD = 105 kHz^2) CG vowel areas. A linear regression model ($F(3, 784) = 64.38$, $p < 0.0001$, with adjusted $R^2 = 0.2$) for the effects of *stress*, *variety* and the interaction of *stress* and *variety* on vowel space area was calculated (the model at the intercept was $\beta = 298.49$, $t(784) = 33.48$, $p < 0.0001$). *Stress* ($\beta = -103.95$, $t(784) = 12.6$, $p < 0.001$) and the interaction of *stress* × *variety* ($\beta = -36.05$, $t(784) = -2.022$, $p < 0.05$) had a significant effect on vowel space area. In contrast, *variety* had no significant effects on vowel space area ($\beta = 5.84$, $t(784) = 0.5$, $p = 0.06$).

Tables 3 and 4 report the results of the linear mixed effects models. *Vowel* and *stress* have significant effects on the F1. The interactions between *vowel* and *stress*, *vowel* and *variety*, *stress* and *variety*, and *vowel* and *stress* and *variety* have a significant effect on the F1. In addition, *stress* and the interactions between *vowel* and *stress*, *vowel* and *variety*, and *stress and variety* have a significant effect on the F2. Most importantly, SMG unstressed /i/ and /u/ vowels are more raised than CG unstressed vowels. This is evident by the significant slopes of /i/ and /u/ reported in Table 8. Also, SMG unstressed vowels are more central than CG vowels (Fig. 3, left panel).

4.2 F3 Values

Figure 4 displays box and whisker plots, which represent graphically the quartiles of F3. The bottom and top of the box show the first and third quartiles, respectively, and the dark solid line inside the box shows the median. The edge of the upper whisker represents the maximum value of F3 and the edge of the lower whisker the minimum value of F3.

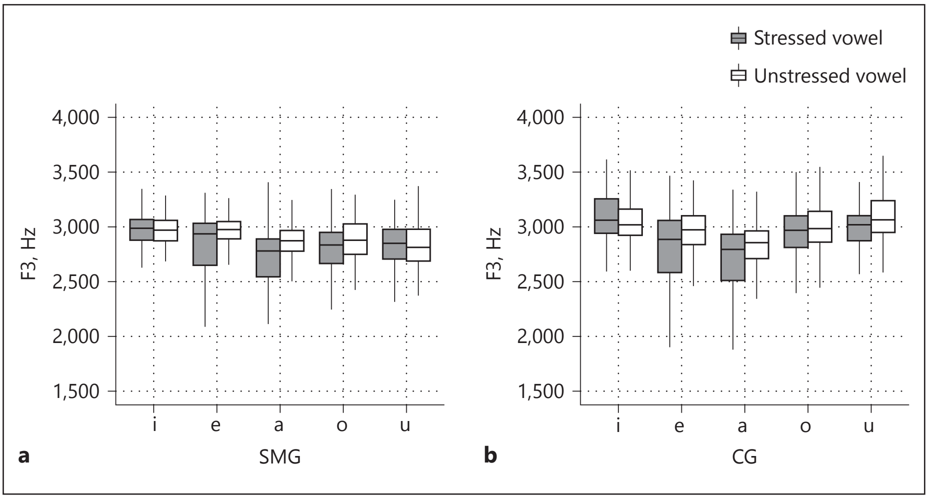

Fig. 4. SMG (left panel, **a**) and CG (right panel, **b**) *F*3 in Hertz for stressed and unstressed vowels.

Table 5. Results of the Linear Mixed Model for *F*3

Response: *F*3	Chisq	Df	Pr(> χ^2)
Vowel	481.08	4	<0.0001
Stress	55.9953	1	<0.0001
Variety	1.964	1	0.16
Vowel: Stress	30.9035	4	<0.0001
Vowel: Variety	175.8272	4	<0.0001
Stress: Variety	1.5349	1	0.21
Vowel: Stress: Variety	16.0601	4	<0.01

SMG front vowels /i/ and /e/ associate with higher F3 than back vowels in both stress and unstressed condition. However, CG vowels do not follow this pattern: In CG, it is the high vowels /i/ and /u/ that are associated with higher F3 values whereas mid vowels /e/ and /o/ are associated with low F3; the low central vowel /a/ has the lowest F3.

SMG – stressed: i > e > u > o > a
SMG – unstressed: i > e > u > o > a
CG – stressed: i > u > o > e > a
CG – unstressed: u > i > o > e > a

Table 5 reports the results of the generalized mixed model for F3. The findings show significant effects of *vowel*, *stress*, and of the interactions *vowel* and *stress*, *vowel* and *variety*, and *vowel* and *stress* and *variety* on F3 These effects resulted in significantly different slopes for the SMG /i/, SMG /u/, and SMG /o/ vowels (see Table 8).

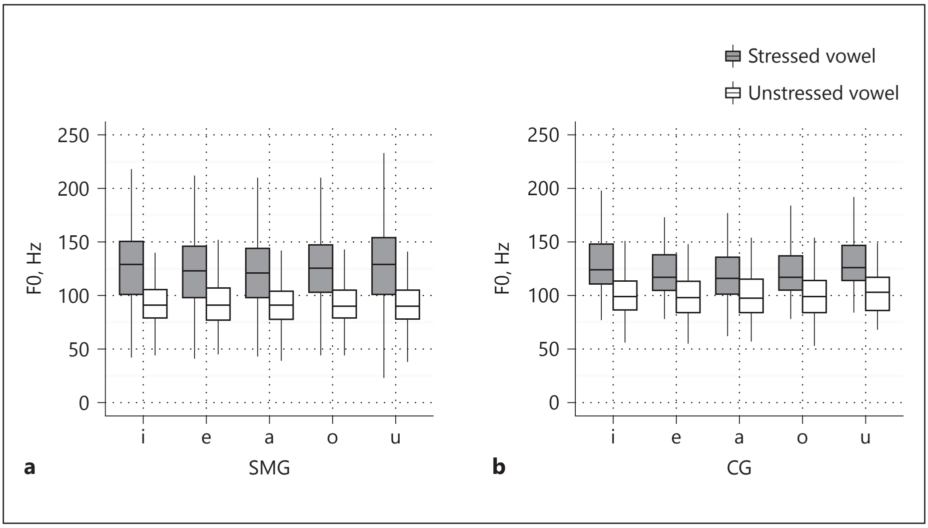

Fig. 5. The F0 in Hertz for stressed and unstressed vowels in SMG (left panel, **a**) and CG (right panel, **b**).

Table 6. Results of the Linear Mixed Model for *F*0

Response: *F*0	Chisq	Df	Pr(> χ^2)
Vowel	16.9	4	<0.01
Stress	467.12	1	<0.001
Variety	0.30	1	0.59
Vowel: Stress	7.57	4	0.10
Vowel: Variety	6.73	4	0.15
Stress: Variety	54.90	1	<0.001
Vowel: Stress: Variety	2.62	4	0.62

4.3 F0 Values

High vowels /i/ and /u/ have the highest intrinsic F0, mid vowels /e/ and /o/ follow. The vowel /a/ has the lowest intrinsic F0, in all cases except for the SMG unstressed vowels – in that case, the intrinsic F0 is approximately the same for all vowels. The results of the linear mixed model for F0 are shown in Figure 5. Table 6 reports the effects of the specific parameters on this model. Specifically, there are effects of *vowel* and *stress* but not of *variety* on the F0. The *variety* had significant effects primarily on the /i/ and /u/ vowels, see Table 8.

4.4 Duration

Figure 6 shows the vowel duration for stressed and unstressed vowels in SMG and CG. From the longest to the shortest vowels, the results are the following:

SMG – stressed: a > o > e > u > i
SMG – unstressed: a > o > e > u > i

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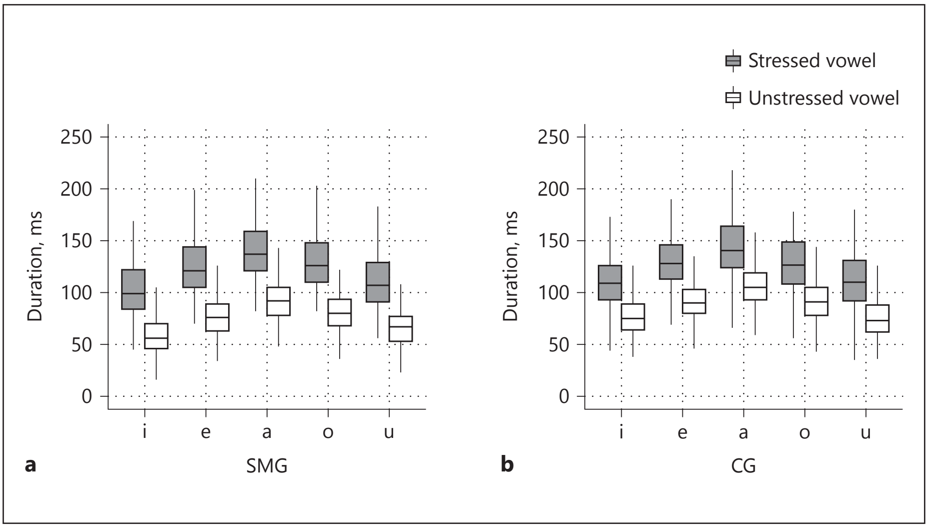

Fig. 6. SMG (left panel, **a**) and CG (right panel, **b**) stressed and unstressed vowel duration in ms.

Table 7. Results of the Linear Mixed Model for Duration

Response: *Duration*	Chisq	Df	Pr(> χ^2)
Vowel	114.02	4	<0.0001
Stress	360.72	1	<0.0001
Variety	2.52	1	0.112
Vowel: Stress	0.79	4	0.926
Vowel: Variety	38.002	4	<0.0001
Stress: Variety	116.24	1	<0.0001
Vowel: Stress: Variety	1.02	4	0.90

CG – stressed: a > e > o > i > u
CG – unstressed: a > o > e > i > u

Stressed vowels are longer than unstressed vowels. CG vowels are longer than the SMG vowels (Fig. 6). The overall multiple regression model for vowel duration is the following: multiple $R^2 = 0.54$, adjusted $R^2 = 0.54$, $F(19, 3{,}328) = 205.8$, $p < 0.0001$. The predicted F0 at the intercept was $b = 146$, SE = 1.83, $t = 79.58$, $p < 0.001$. The specific effects of *vowel*, *stress*, and *variety* are reported in Table 7. *Vowel* and *stress* and the interaction of *variety* and *stress* have a significant effect on duration (Table 7).

5 Discussion

Distinct sociolinguistic features, often delimited by certain geographic boundaries (a.k.a. isoglosses), may distinguish language varieties. However more commonly,

Table 8. Results of the Linear Mixed Models with the significant contributions for F1, F2, F3, F0, and Duration

		Estimate	SE	df	t	Pr(>|t|)
F1	(Intercept)	906.46	12.94	55	70.04	0.001
	e	–325.98	16.83	40	–19.37	0.001
	i	–499.76	16.63	38	–30.05	0.001
	o	–321.48	16.83	40	–19.11	0.001
	u	–462.72	16.84	40	–27.48	0.001
	Unstressed	–126.74	16.15	39	–7.85	0.001
	e:Unstressed	48.48	23.67	41	2.05	0.050
	i:Unstressed	105.89	23.37	39	4.53	0.001
	o:Unstressed	51.19	23.67	41	2.16	0.050
	u:Unstressed	76.84	23.68	41	3.25	0.010
	e:SMG	64.18	12.50	4341	5.14	0.001
	o:SMG	50.23	12.47	4338	4.03	0.001
	Unstressed:SMG	–58.25	11.54	4339	–5.05	0.001
	i:Unstressed:SMG	78.54	17.19	4337	4.57	0.001
	u:Unstressed:SMG	71.85	17.64	4343	4.07	0.001
F2	(Intercept)	1589.82	44.29	43	35.89	0.001
	e	393.70	60.99	36	6.46	0.001
	i	958.63	60.62	35	15.82	0.001
	o	–352.10	60.98	36	–5.77	0.001
	u	–370.31	61.00	36	–6.07	0.001
	u:Unstressed	218.69	85.20	38	2.57	0.050
	i:SMG	–123.00	31.86	4323	–3.86	0.001
	Unstressed:SMG	68.23	30.21	4324	2.26	0.050
F3	(Intercept)	2634.76	28.34	770	92.98	0.001
	e	179.08	27.28	720	6.57	0.001
	i	448.19	26.05	570	17.21	0.001
	o	311.72	27.24	720	11.44	0.001
	u	379.48	27.32	720	13.89	0.001
	Unstressed	104.23	24.73	460	4.22	0.001
	i:Unstressed	–148.29	36.76	580	–4.03	0.001
	i:SMG	–154.52	35.70	42900	–4.33	0.001
	o:SMG	–179.58	36.60	43070	–4.91	0.001
	u:SMG	–212.74	36.69	43060	–5.80	0.001
	Unstressed:SMG	82.54	33.79	41890	2.44	0.050
	u:Unstressed:SMG	–189.67	51.73	42950	–3.67	0.001
F0	(Intercept)	117.56	5.05	60	23.28	0.001
	i	10.44	2.86	38	3.65	0.001
	u	14.35	2.91	41	4.94	0.001
	Unstressed	–17.28	2.78	39	–6.22	0.001
	u:Unstressed	–11.36	4.10	42	–2.77	0.010
	i:SMG	–4.72	2.30	4309	–2.05	0.050
	u:SMG	–5.61	2.37	4320	–2.37	0.050
	Unstressed:SMG	–10.11	2.18	4311	–4.63	0.001
Duration	(Intercept)	145.32	4.61	76	31.52	0.001
	e	–15.12	5.07	35	–2.98	0.010
	i	–33.96	5.05	34	–6.73	0.001
	o	–17.04	5.07	35	–3.36	0.010
	u	–32.79	5.07	35	–6.46	0.001
	Unstressed	–38.15	4.77	43	–8.00	0.001
	o:SMG	7.55	2.37	4323	3.18	0.010
	u:SMG	4.80	2.38	4338	2.02	0.050
	Unstressed:SMG	–11.01	2.19	4323	–5.02	0.001

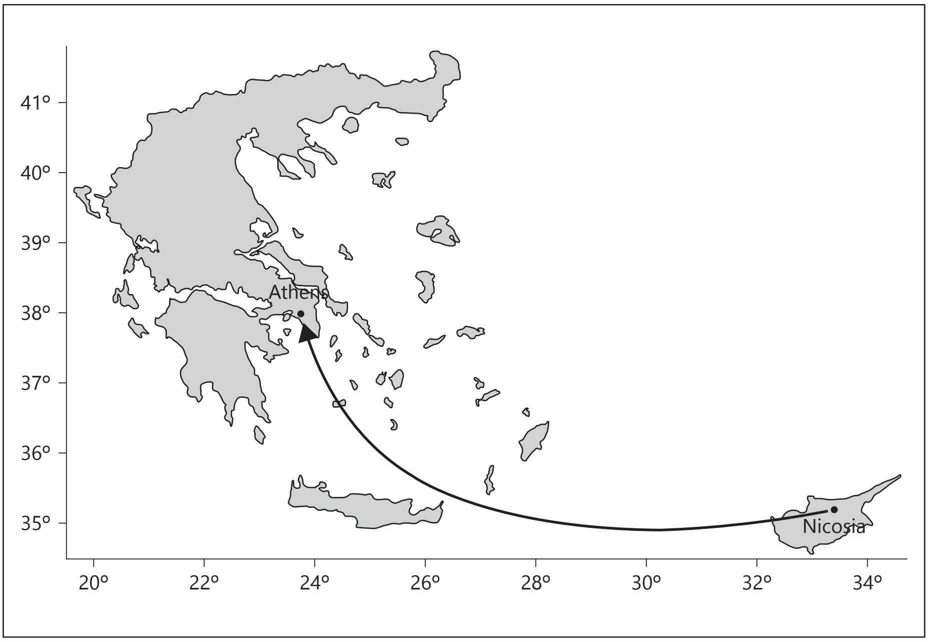

Fig. 7. Vowel raising and geography.

sociophonetic variation unfolds as a gradient change in the acoustic structure of speech (Labov, 1994). By comparing the vowels of SMG and CG, this study shows that the SMG unstressed vowels are overall more reduced than the CG vowels and that the SMG unstressed /i a u/ vowels are more raised than the corresponding CG vowels, and this argues that their differences are part of the gradient effects of vowel raising and vowel reduction that take place in the Modern Greek dialect continuum.

Stress shapes the acoustic properties of Greek vowels (e.g., for SMG, see Fourakis et al., 1999, and for CG, see Themistocleous, 2011, 2014, who provide evidence on the effects of stress on vowel duration). In both varieties stressed vowels are overall more peripheral than unstressed vowels and occupy a greater vowel space. Consequently, stress results in significant effects on both the F1 and the F2. The F1 of unstressed vowels is overall higher than the F1 of stressed vowels. The F2 determines the front-back dimension: the unstressed front vowels /i/ and /e/ associate with lower F2 than the stressed /i/ and /e/ whereas the F2 of the unstressed vowels /o/, /u/, and /a/ is higher than F2 of the stressed vowels.

Also, the stress has different effects on the vowels of the 2 varieties. Overall, the unstressed SMG /i/ and /u/ vowels are more raised and more central than the unstressed CG vowels. Moreover, the unstressed vowels in both varieties are more reduced than the stressed vowels. Vowel reduction is reflected in the unstressed vowels by a shorter vowel duration and a smaller overall vowel space area. Again, the effects of vowel reduction are stronger in SMG than in CG. SMG unstressed vowels are significantly shorter than the CG unstressed vowels and the SMG vowel areas of unstressed vowels are 18% smaller than the corresponding unstressed CG vowel areas (see the section F1 × F2).[1]

Overall, the interaction of vowel × variety resulted in significant effects on the F3. The CG high vowels /i u/ and the back /o/ had a significantly higher F3 than the corresponding SMG vowels. This can suggest that the SMG vowels exhibit more lip-rounding (and that they are also produced with more forward tongue dorsum constrictions) than the CG vowels (Harrington, 2010, p. 87).

The study also replicates earlier studies that show that the high vowels associate with higher F0 than the mid vowels and the low vowels (see also Peterson and Barney, 1952; Lehiste, 1970; Reinhold Petersen, 1978; Shadle, 1985; Beckman, 1986; Fourakis et al., 1999; Nicolaidis, 2003; Nicolaidis and Rispoli, 2005). There was no effect of the language variety on F0, yet there was a significant effect of stress and variety on the F0. Overall, stressed vowel F0 is higher than unstressed vowel F0. The stressed vowels do not differ in their F0 in the 2 varieties. By contrast, the F0 of the unstressed vowels is higher in CG than in SMG, which might indicate variety-specific intrinsic F0 (Van Hoof and Verhoeven, 2011). However, most probably it is the differences in the SMG and CG tonal structures that may account for the effects of variety × stress on F0 (for a comparative presentation of SMG and CG tonal structures, see Themistocleous, 2011, 2015).

Based on vowel raising and reduction, earlier scholars distinguished Greek varieties into 2 main groups: the northern varieties and the southern varieties (Kontosopoulos, 1981, 2011; Newton, 1972b; Trudgill, 2003). According to these scholars vowel raising and reduction characterize the northern varieties only (Kontosopoulos, 1981, 2011; Newton, 1972b; Trudgill, 2003). Based on the evidence from SMG and CG reported here, we argue that the vowel raising and reduction observed in the northern varieties are the culmination of acoustic effects that develop in a gradient manner within the Greek dialectal continuum following the direction of the arrow shown in Figure 7 from less strong to stronger effects of vowel raising and reduction. They are less strong and not perceptually salient in the southern Greek varieties – such as CG and SMG – and become perceptually salient in the northern varieties, where for instance, one vowel category shifts into another vowel category (e.g., /e/ → /i/ or [o] → /u/). These gradient effects of vowel raising and reduction from the south to the north may account for the differences observed in the acoustic properties of SMG and CG vowels.

It should be pointed out that vowel raising and reduction involve the comparison of vowels of one variety with the vowels of another variety. This point is important as it explains the cause of disagreements that arose in the literature concerning the realization of vowel raising and reduction in Modern Greek dialects. The reason is that different studies employ different points of reference. Some compare the SMG vowels to the vowels of the northern varieties (e.g., Chatzidakis, 1905; Kontosopoulos, 1981,

[1] There can be significant effects of stress on vowel duration depending on the type of stress (i.e., lexical, post-lexical), the position of the vowel in the word (antepenultimate, penultimate, ultimate etc.), the presence or absence of pitch accents/boundary tones, etc. For example, Themistocleous (2014) shows that CG vowel duration is longer in polar questions than in statements. (Note that in this speech variety, statements and questions are segmentally identical; they only differ in their melodies.) The findings showed that there are different lengthening patterns in statements and questions. To distinguish this type of lengthening from the final lengthening that usually applies at the end of an utterance, Themistocleous (2014) called it edge-tone lengthening.

2011; Newton, 1972b); in these accounts, SMG and CG vowels are identical as they do not exhibit vowel raising. In contrast, other studies compare the SMG and CG vowels and suggest that the vowels of these 2 varieties can be different (e.g., Menardos, 1894).

To conclude, vowels vary in multifarious ways, often prominently and distinctively and often in subtle and gradient ways, under the level of consciousness of people. Yet, vowel variation is not wild and anarchic but it is rich in linguistic and sociolinguistic information (e.g., Labov, 1994; Labov et al., 2006; Foulkes and Docherty, 2006; Fox and Jacewicz, 2009). Gaining insights from a controlled experimental design, instrumental analysis, and statistical investigation, this study sheds light onto the gradient effects of vowel variation in Greek. In fact, the study presented here gathers and compares acoustic material from urban SMG and CG vowels, thus hopefully making them accessible to a broader audience of scholars of all theoretical orientations. Moreover, the study contributes to the overall research on sociophonetics, by providing an example of acoustic variation from Greek varieties.

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