Voiced stop prenasalization in two dialects of Greek

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This study examined the phonetic realization of voiced stops in the Cretan and Thessalonikan dialects of Modern Greek. Six males and six females of each dialect were recorded in a sentence-reading task. Duration and amplitude were measured to compare the degree of nasality of voiced stops to that of nasals in different phonetic contexts. Results showed that amplitude changes during the voicing bar of the voiced stops varied both within and across speakers. In some instances, there was consistently low amplitude throughout the voicing bar (characteristic of voiced stops), whereas in other instances, there was high amplitude at the closure onset followed by decreasing amplitude toward the burst (characteristic of prenasalization). By contrast, nasals had consistently high amplitude throughout the murmur. The mixed-effects models suggest that there were complex and interactive influences of dialect, gender, prosodic position, and stress in realizing prenasality in the voiced stops. In particular, Cretan male speakers showed the least clear tendency of prenasalization consistent with earlier impressionistic studies. Furthermore, productions of Cretan males showed less prenasalization than those of females in both prosodic positions. The procedures in this study can be used to describe prenasalization in other dialects or languages where prenasalization has been observed. © *2012 Acoustical Society of America*. [http://dx.doi.org/10.1121/1.4750488]

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I. INTRODUCTION

Dialectal variation has long attracted the interest of linguists in various subfields because it serves as a window into both diachronic and synchronic language change. Traditionally, phonological variation across dialects has been described in categorical terms with little attention to the fine-grained phontic detail of this variation. This is not always problematic in that some phonological dialectal differences are categorical, such as the difference between the three-way sibilant fricative contrast in Beijing Mandarin as compared to the two-way sibilant fricative contrast in Taiwanese Mandarin. However, many differences in speech sounds between dialects are much more difficult to describe categorically, such as the differences between mid and high lax front vowels across American English dialects.

In recent years, phoneticians have developed both the experimental methods and the statistical tools needed to more precisely describe gradient differences between dialects that might go undetected in traditional impressionistic phonological analyses. Research in this area has revealed significant differences in the pronunciation of both vowels and consonants among dialects (e.g., Clopper and Pisoni, 2006; Clopper *et al.*, 2005; Gonzalez, 2002; Hagiwara, 1997; Hillenbrand *et al.*, 1995; Jacewicz *et al.*, 2006; Jacewicz *et al.*, 2009; Leinonen, 2008; Recasens and Espinosa, 2007; among others). This paper follows in this new tradition and focuses on dialectal variation in voiced stop productions in modern Greek (henceforth Greek) in which the presence or absence of prenasalization has been proposed by several researchers as a diagnostic feature for dialect classification in this language (Triandafyllidis, 1938, pp. 66–67; Trudgill, 2003; Tzitzilis, 2001).

A. Dialectal variation in Greek

Several impressionistic studies have documented the existence of dialectal differences in both vowel and consonant productions in Greek (Newton, 1972; Trudgill, 2003). However, with only few exceptions (Baltazani and Efthymiou, 2009; Baltazani and Topinzi, 2010; Christou and Baltazani, 2007; Loukina, 2010; Tserdanelis and Arvaniti, 2001), there is limited phonetic work on dialectal variation in Greek. The current study aimed to contribute to this area of dialect research by examining the differences between speakers from northern Greece (Thessaloniki) and southern Greece (Crete), specifically in terms of the way the stop segments /b/, /d/, and /g/ are phonetically realized.

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Most varieties of Greek have a two-way voicing contrast in stop consonants (voiceless /p/, /t/, /k/ vs voiced /b/, /d/, /g/). Voiceless stops are phonetically unaspirated with short-lag VOT (Voice Onset Time, Lisker and Abramson, 1964) values, whereas voiced stops are pre-voiced with lead VOT values (Botinis *et al.*, 2000). Greek voiced stops have been reported to be highly variable in their phonetic realizations (e.g., Arvaniti, 2007). Historically, most Greek voiced stops were derived from Classical Greek sequences of nasal plus stop (and this is how they are represented orthographically, i.e., /b/ in the word *τεμπέλης* /te' belis/ "lazy" is spelled as a sequence of a nasal and a stop ⟨*μπ*⟩), while Classical Greek voiced stops were spirantized to become voiced fricatives in the modern language. Many speakers of Greek still produce voiced stops as clusters or as prenasalized stops in at least some prosodic environments, such as in word-medial position (Arvaniti, 2007; Arvaniti and Joseph, 2000).

Prior research has established that the degree of prenasalization in Greek voiced stops varies according to dialect, idiolect, social register, rate of speech, and a host of other factors. Within a single dialect, voiced stops can be realized in different ways depending on various sociolinguistic factors. Arvaniti and Joseph (2000) examined phonetic variation in voiced stops spoken in Athens, finding that prenasalization was more prevalent among older Athenian speakers (>40 yr) than young speakers and more frequent in cases of slow, deliberate speech rather than in fast speech, especially among female speakers. Their findings corroborated those of earlier smaller-scale studies on stylistic variation in voiced stop prenasalization in Greek (e.g., Charalambopoulos *et al.*, 1992, for Thessalonikan Greek; Pagoni, 1989, for Athenian Greek).

The presence or absence of prenasalization also differs systematically across dialects. In Cypriot Greek, voiced stops are always prenasalized (Arvaniti, 1999), while in the two mainstream dialects of Greek, spoken in Thessaloniki and Athens, voiced stops are realized with variable prenasalization (Arvaniti and Joseph, 2000; Charalambopoulos *et al.*, 1992). Finally, in Cretan Greek, voiced stops tend to be produced without prenasalization (e.g., Contossopoulos, 2001; Granqvist, 1997). Thus a word like *πέντε* /'pede/ "five" might be pronounced in Cyprus as ['pende], in Athens as ['pe^{n}de] (with a [d] which is slightly prenasalized), and in Crete as ['pede] (Newton, 1972).

B. Acoustic measures of prenasalization

Prenasalization denotes complex phonetic articulations that are produced with an accompanying nasal murmur during all (or part of) the stop closure (Arvaniti, 2007; Burton *et al.*, 1992; Chan and Ren, 1987; Demolin *et al.*, 2006). The articulation of prenasalized stops differs from that of nasals with regard to the timing of the gestures of oral release and velopharyngeal port closure. Specifically, in prenasalized stops, the velopharyngeal port closes before the release of the oral closure, while in nasals, the velopharyngeal port remains open at least until the moment of the oral release. This difference in timing between prenasalized stops and nasals results in different intra-oral pressure changes during the stop closure and nasal duration. Thus either amplitude or duration properties of the voice bar may be useful to acoustically describe prenasalization.

The earliest studies of prenasalization examined temporal characteristics of prenasalized stops to test whether duration differences could differentiate prenasalized stops from other singleton consonants, such as /l/ (Maddieson, 1989, in Fijian; Ladefoged and Maddieson, 1986, in Sinhalese; Burton *et al.*, 1992, in Moru). These studies concluded that duration did not play a significant role in differentiating prenasalized stops from the other consonants in question. In Burton *et al.* (1992), while prenasalized stops tended to have a longer closure interval than voiced stops and nasals in Moru, duration distributions of the three target categories widely overlapped. Although duration was not a successful acoustic metric to differentiate prenasalized stops from nasals in previous studies of several languages, it has not yet been applied to Greek voiced stops to examine dialectal variation.

Amplitude differences turned out to be a more robust way of differentiating prenasalized stops from other consonants in previous studies. Burton *et al.* (1992) found different amplitude trajectory patterns during the closure and the nasal murmur among the three consonant categories of nasals, voiced stops, and prenasalized stops in Moru, a central Sudanic language (see Fig. 6 of Burton *et al.*, 1992). Nasal consonants had overall high amplitude throughout the murmur, whereas voiced stops had generally low amplitude throughout the voice bar. Prenasalized stops began with high amplitude as in nasals and ended with low amplitude as in voiced stops, resulting in a falling amplitude trajectory. In their inspection of spectrums, the spectral characteristics of prenasalized stops during the initial portion of the closure duration were similar to those of nasal consonants by having the second and the third spectral peaks at a high frequency range. Similarly, Chan and Ren (1987) described the prenasalized stops in Malagasy as having an amplitude drop preceded by a relatively strong nasal murmur. The amplitude envelope of Malagasy prenasalized stops displayed a falling trajectory starting from the highest amplitude of the nasal murmur (see Fig. 4 of Chan and Ren, 1987). Kong (2009) used this amplitude measure to compare word-initial voiced stops and nasals in Greek produced by adult and child speakers of Thessalonikan Greek. She found that voiced stops spoken by adults had a similar level of amplitude as nasals at the beginning of the voice bar and an amplitude drop immediately before the release of the oral closure. Her study also showed that there were individual differences in the degree of prenasalization in voiced stops, suggesting that Thessalonikan speakers optionally prenasalized their voiced stops. These results provided phonetic confirmation of earlier impressionistic accounts of dialectal differences in Greek.

C. The present study

The current study aimed to provide acoustic evidence of prenasalization in voiced stops spoken in Thessaloniki (Greece's second largest city, northern Greece) and Crete (in the district of Ierapetra, in southeastern Greece) and to use mixed-effects regression models to quantify differences between the two dialects. We measured both temporal and amplitude characteristics of voiced stops produced by speakers of Thessalonikan and Cretan Greek so as to capture dialectal differences in realizing prenasality in voiced stops. Nasal consonants were also included in our analysis so that we could ensure that our measures successfully captured acoustic characteristics of nasality in Greek. We examined voiced stops and nasals in different prosodic and post-consonantal stress conditions as produced by both male and female speakers of these two dialects of Greek. This study provides experimental data for voiced stop variants across dialects in Greek and quantifies prenasalization more broadly.

II. METHODS

A. Procedures

1. Participants

Twenty-four Greek-speaking adults between 20 and 61 yr participated in the study. There were 12 speakers (6 male and 6 female) from each dialect. Participants were born and raised in either north-central Greece (the Thessaloniki area) or south-eastern Greece (the Ierapetra area of the island of Crete). Based on information from a demographic questionnaire, the two participant populations were generally similar in terms of age (mean = 39 yr, range = 21–61 yr for Thessalonikans; mean = 36.7 yr, range = 23–58 yr for Cretans) and level of education (mean = 15.2 yr of schooling, range = 12–18 yr for Thessalonikans; mean = 14.9 yr of schooling, range = 12–18 yr for Cretans). None of the participants were bilingual or had any substantial experience using a foreign language. None reported a speech, language, or hearing disorder.

2. Stimuli

The stimuli were familiar real words, each containing one of the Greek voiced stops (/b/, /d/, /g/) or nasals (/m/, /n/) in word-initial or word-medial position (see Appendix). The vowel following the target consonant varied among the five vowels of Greek (i.e., /a/, /e/, /i/, /o/, /u/). In half of the words, the syllable containing the onset /b, d, g, m, n/ was stressed, and in the other half of the words, it was unstressed. For example, target /d/ in the vowel /a/ context was elicited in the Greek words *ντάμα* /ˈdama/ "queen of hearts" and *νταλίκα* /daˈlika/ "truck" in word-initial position and in *λιοντάρι* /lioˈdaɾi/ "lion" and *πάντα* /ˈpada/ "always" in word-medial position.

3. Procedure

Recordings were made in a quiet room in the participant's or the researcher's home. The target words were presented on a laptop computer in randomized order. Participants read sentences of the form "*target word* [ˈtoɾa ˈipa] ("*I've just said*") *target word*." For the Cretan speakers, we replaced the standard form *τώρα* (/ˈtoɾa/, *now*) with the Cretan dialectal form *εδά* (/**eˈða**/, *now*) in the carrier phrase to facilitate elicitation of the Cretan dialectal features. For example, if the target was the word *πάντα* (/ˈpada/, *always*), then subjects read "**πάντα** *τώρα είπα* **πάντα**" if they spoke the Thessalonikan dialect, and "**πάντα** *εδά είπα* **πάντα**" if they spoke the Cretan dialect. The sentences were presented in Greek orthography, and stress was marked according to the conventional orthography of Greek. The participants' utterances were recorded directly onto a hard drive disk at a 44.1 kHz sampling rate. A supercardioid condenser microphone (AKG C 5900 M/TM 40) was used, placed on a microphone stand facing the subject. Participants were instructed to read each sentence at a comfortable rate of speech. All participants were recorded by the same experimenter (the second author), who is a native speaker of Greek from the Thessaloniki region. Recordings of the Cretan dialect speakers were made in the presence of a native dialect informant so that speakers would be comfortable using their dialect features. Only the words elicited utterance-initially were included in the present study. Data from one female Cretan speaker were excluded from the analysis due to noise in the recording. In total, 4508 tokens were used in the analysis. Forty-six tokens were excluded due to (1) spirantization-like signal (e.g., irregular high frequency noise during voicing lead, particularly in Cretan speakers' productions), (2) considerable background noise, and (3) failure to realize the targeted prosodic condition (i.e., no perceptually identifiable break before a word-initial token due to speakers' fast rate of speech.)

B. Analysis

1. Acoustic measurements

a. Preliminary analysis of spectral patterns. While the focus of this paper was on examining duration and amplitude trajectories as in Burton *et al.* (1992), we also conducted a qualitative examination of the differences in spectral patterns among voiced stops, prevoiced stops, and nasals. Figures 1 and 2 show spectral patterns of two glottal pulse windows taken at three different time points (onset, middle, and offset locations during voice bar and nasal murmur). Three distinct patterns were observed; these were consistent with what Burton *et al.* (1992) described for phonological categories of nasals, prenasalized stops, and voiced stops in Moru. First, for nasals, weak energy concentrations were found at a high frequency region throughout the nasal murmur. This can be observed in the spectrogram of the nasal consonant in a word-initial unstressed token in the left-most panel of Fig. 1. The overlaid spectrums of the nasal token showed that the amplitudes of the first spectral peaks in the three measurement locations did not show a noticeable difference; this suggested a level amplitude trajectory during the murmur. Unlike nasals, voiced stops showed several different spectral patterns during the closure. One pattern was similar to that of the prenasalized stops described in Burton *et al.* (1992). For these productions, weak energy concentrations (similar to what was observed in nasal murmurs) were observed at the initial portion of closure duration. These nasal-like spectral characteristics disappeared gradually toward the burst. This can be seen in the spectrogram of a voiced stop in a word-initial unstressed syllable in the center panels of Fig. 1. Overlaid spectrums show that the amplitudes of the first spectral peaks were highest in the spectrum of the closure onset and lowest in the spectrum of the closure offset with

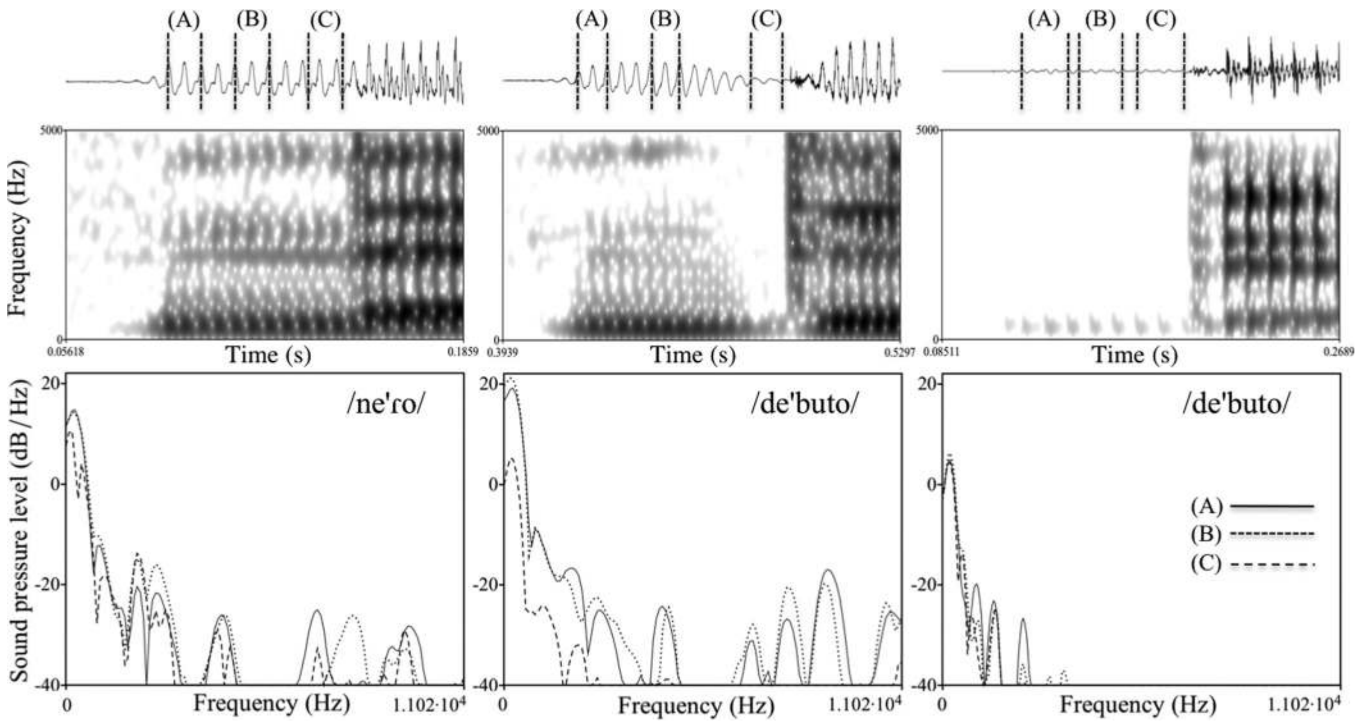

FIG. 1. Spectrograms, waveforms, and overlaid spectrums analyzed at three different time points in the nasal murmur and stop closure. The examples are word-initial /n/ in /ne'ro/ ("water") and /d/ in /de'buto/ ("first professional appearance") produced by a Thessalonikan female (left and center panels) and a Cretan male (right-most panels).

more than a 10 dB difference between onset and offset. This spectral pattern shows a falling amplitude trajectory during stop closure duration. A second pattern was similar to that of the prevoiced stops described in Burton *et al.* (1992). Such productions (as in the example of a voiced stop in right-most panels of Fig. 1) show a clear voicing bar continuously throughout the closure duration without any evidence of a nasal-like formant. Overlaid spectrums did not exhibit differences among the amplitudes of the first spectral peaks taken at the three time points, a pattern that also suggests a level amplitude trajectory. This pattern was differentiated from that of the nasal tokens by having a lower amplitude when the amplitudes were normalized with reference to the amplitude of the following vowel. Besides these two extreme examples, there were other voiced stops with varying degrees of nasal-like energy at the closure onset based on observation of the spectrograms. This same relationship between spectral characteristics and amplitude trajectory patterns was also observed in word-medial tokens, shown in Fig. 2.

These qualitative observations support our use of amplitude trajectories to quantify the degree of prenasalization in voiced stops collected from the two Greek dialect groups. That is, we observed that the presence of nasal energy at closure onset and its disappearance toward the burst was consistent with falling peak amplitude trajectories during closure duration. Conversely, the absence of nasal energy at closure onset was consistent with flat amplitude trajectories. Therefore we propose (as did Burton *et al.*, 1992) that falling amplitude trajectories during closure can be used to indicate varying degrees of prenasalization: Steep falls indicate a high degree of prenasalization, whereas shallow falls indicate weak or little prenasalization.

b. Duration and amplitude trajectories. The duration of prevoicing lead in the voiced stops was measured by calculating the interval between the onset of the burst and the first indication of voicing preceding it. These two acoustic landmarks were identified by detecting an abrupt energy rise after the closure (burst) and the voice bar in the spectrogram (voice onset). The duration of each nasal consonant was measured by subtracting the onset of the nasal murmur from the onset of the following vowel.

The amplitude trajectory was estimated by connecting the amplitude values measured at each glottal pulse during the voice bar and nasal murmur. The amplitude was measured by taking the first peak amplitude in an FFT spectrum made from a 6 ms Hamming window centered at each glottal pulse. The series of amplitude values was normalized based on the amplitude of the following vowel. The vowel amplitude was measured by taking the amplitude of the first harmonic in the spectrum of a 25.6 ms analysis window starting at the third pulse after the burst. This normalization procedure was necessary to compare the amplitude values over time across tokens and across speakers. Figure 3 illustrates how the amplitude values were measured and normalized.

2. Statistical analysis

We used two ordinary least-squared mixed-effects regression models to analyze the duration and amplitude patterns. For the mixed-effects regression model for the duration analysis, the dependent variable was voiced stop or nasal duration, and the three independent variables were dialect (Cretan vs Thessalonikan), gender (male vs female), and stress condition (stressed vs unstressed). The model for the

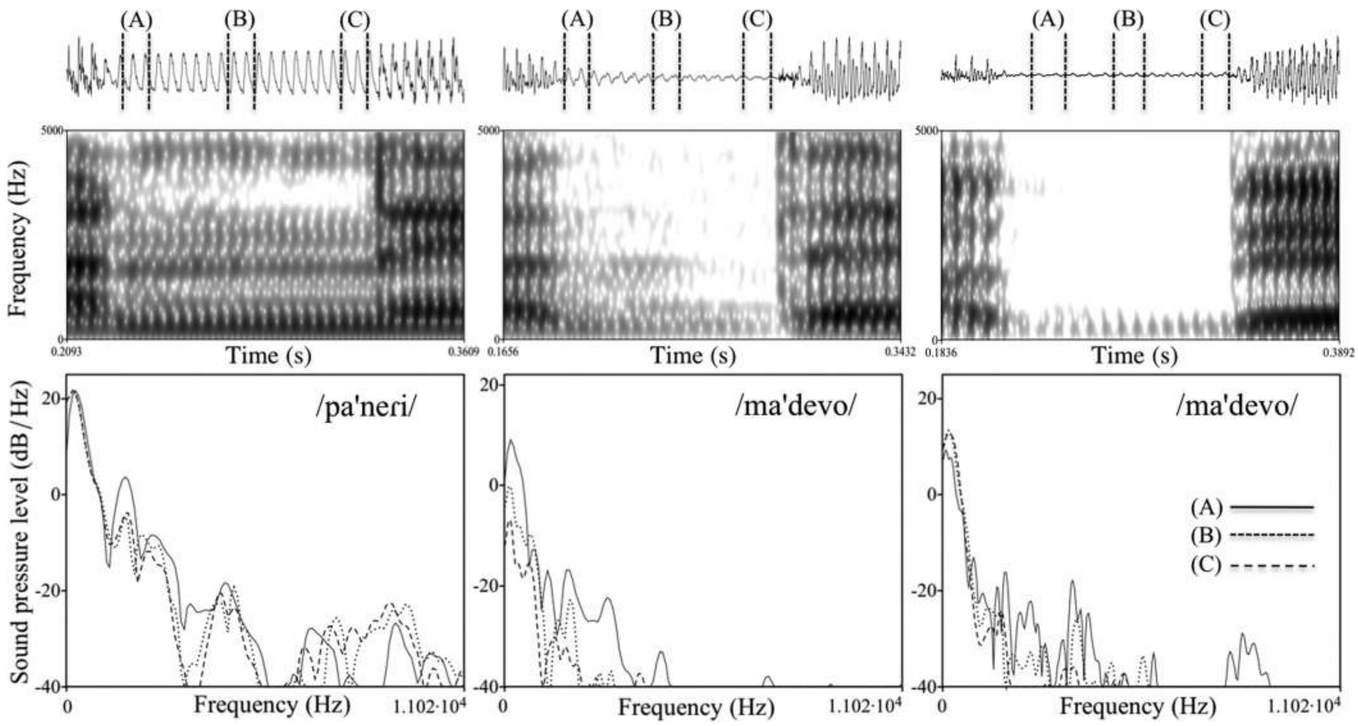

FIG. 2. Spectrograms, waveforms, and overlaid spectrums analyzed at three different time points in the nasal murmur and stop closure. Target consonants are word-medial /n/ in /pa'neɾi/ "basket" and /d/ in /ma'devo/ "I guess" produced by a Thessalonikan female (left and center panels) and a Cretan male (rightmost panels).

duration analysis had a random intercept and slope at the speaker level to allow for individual differences with respect to the testing factors.

The statistical analysis that we used for the amplitude trajectory analysis was more complex. We decided that these data would be most appropriately analyzed with time series data analysis, which has been used for analyzing longitudinal growth curves and eye-tracking data. In these cases, as in the case of amplitude trajectories, the data collected at one point in time are dependent on values collected at adjacent points in time (Barr, 2008; Mirman *et al.*, 2008; Singer and Willett, 2003). Therefore we modeled the normalized amplitude during the voice bar and nasal murmur as a function of time in a mixed-effects regression model as outlined in Mirman *et al.* (2008). In this amplitude trajectory model, linear time was a fixed effect, and speakers and tokens were random effects. The intercept and slope of linear time were allowed to vary at both the token and speaker level. This amplitude trajectory model included a first order term (linear slope) in which the direction and degree of the linear term coefficient indicated whether and how steeply the amplitude fell during the voice bar and nasal murmur. For voiced stops the amplitudes of which immediately before the burst are estimated lower than those of nasals, the linear slope coefficient can indicate the degree of prenasalization of the voiced stop variants in Greek. The presence of a significant linear slope effect in combination with a negative sign of the coefficient indicates that the voiced stop is more or less prenasalized reflecting amplitude decreases over time falling from closure onset to offset. Furthermore, a greater absolute value of the negative linear slope coefficient represents a steeper amplitude fall, indicating the presence of more nasal energy (i.e., a high degree of prenasalization) at the closure onset. In contrast, the absence of a significant linear slope in the model for voiced stops indicates that the amplitude trajectory was flat throughout the closure duration due to a lack of nasalization at stop closure onset. The significances of the linear slope effect and other interacting factors such as dialect, gender, and stress condition were tested by a log-likelihood ratio (or deviance) test (Raudenbush and Bryk, 2002; Snijders and Bosker, 1999), which compares the log-likelihood of the model with the factor to that of the model without the factor. The difference between log-likelihoods was evaluated to determine whether each particular factor significantly improved the model fit. We collapsed consonants across place of articulation in the models, as place of articulation was not a significant factor in preliminary analyses.

III. RESULTS

A. Duration

Regardless of dialect, most voiced stops were produced with lead VOT values in both word-initial and word-medial position. Only 26 of 575 word-initial tokens had lag VOT values in the Cretan speakers' productions, and 39 of 658 tokens had lag VOT values in the Thessalonikan speakers' productions. Voiced stops in both dialects tended to have longer duration than nasals. Mean durations of voiced stops (lead VOT values only) and nasals were 91 and 80 ms, respectively, in word-initial position and 108 and 88 ms in word-medial position (see Table I for mean durations of voiced stops and nasals separated by dialect and prosodic position). This tendency is consistent with the relationship

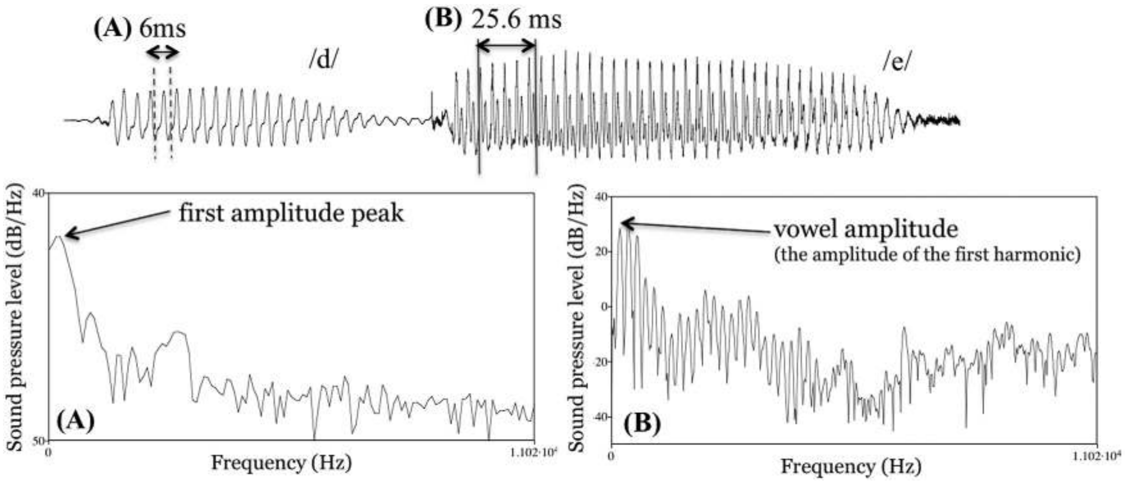

FIG. 3. Illustration of acoustic measurements of amplitude in voiced stops and nasals (A) and in the following vowel (B). Amplitude normalization was performed by subtracting the amplitude value measured at prevoicing or nasal murmur (A) from the amplitude value measured at the following vowel (B).

between word-initial stops and nasals in Moru reported by Burton *et al*. (1992).

The distributions of duration are illustrated in Figs. 4 and 5. It can be observed that the duration of the voice bar is longer than that of the nasal murmur in both dialects. Cretan speakers tended to have a smaller mean duration difference between the two consonant manners (85 and 92.4 ms for nasals and voiced stops, respectively) than Thessalonikan speakers (75.8 and 90.7 ms for nasals and voiced stops, respectively). In addition, duration differences between the two consonant manners were larger in the males' productions than the females'. Furthermore, the duration of the voice bar and nasal murmur was longer overall before stressed than unstressed vowels. However, the magnitude of duration differences between the two consonant types was greater before an unstressed vowel (64.4 ms for nasals and 78.0 ms for voiced stops, respectively) than before a stressed vowel (95.7 ms for nasals and 103.2 ms for voiced stops, respectively).

After excluding the short lag VOT voiced stops, the absolute-duration values of the voice bar and nasal murmur were entered in a mixed-effects regression model to examine the effects of dialect, post-consonantal stress condition, gender, and consonant type. We made two models, one for word-initial and one for word-medial position. The model for the word-initial tokens showed that consonant manner interacted with dialect ($F = 7.0$, df $= 1$, SS $= 0.005$), gender ($F = 5.34$, df $= 1$, SS $= 0.004$), and post-consonantal stress condition ($F = 5.2$, df $= 1$, SS $= 0.004$). These results confirmed three observations: (1) Cretan speakers produced a smaller mean duration difference between voiced stops and nasals than Thessalonikan speakers; (2) male speakers produced larger mean duration differences between the two consonant manners than female speakers; and (3) there were longer mean duration differences before stressed vowels than before unstressed vowels. There was also a significant interaction between post-consonantal stress condition and gender ($F = 11.6$ df $= 1$, SS $= 0.009$), but no significant three-way interaction among stress-condition, gender, and consonant type. In word-medial position, there was a significant three-way interaction among dialect, gender, and stress condition ($F = 16.77$, df $= 1$, SS $= 0.01$). However, consonant manner did not significantly interact with any other factor.

TABLE I. Absolute mean durations (standard deviations) in milliseconds of voice bars and nasal murmurs.

		Cretan		Thessalonikan	
		Stressed	Unstressed	Stressed	Unstressed
Word-initial					
Voiced stops	Female	107 (41)	84 (33)	106 (30)	73 (24)
	Male	100 (35)	76 (32)	99 (41)	80 (37)
Nasals	Female	110 (39)	73 (33)	99 (27)	60 (22)
	Male	93 (33)	65 (27)	83 (29)	59 (25)
Word-medial					
Voiced stops	Female	118 (34)	118 (36)	105 (24)	118 (24)
	Male	100 (33)	104 (28)	104 (35)	101 (37)
Nasals	Female	103 (16)	86 (24)	98 (18)	90 (22)
	Male	87 (31)	73 (22)	93 (28)	76 (26)

B. Amplitude trajectories

Amplitude trajectories of individual speakers during the voice bar and nasal murmur in each dialect are shown in Figs. 6 (word-initial tokens) and 7 (word-medial tokens). Because the absolute duration of the voice bar and nasal murmur varied across tokens and across speakers, we plotted amplitude values as a function of the proportion of time between the onset and the burst. During the initial 20% of the trajectory in word-initial tokens, there was a sharp rise in amplitude followed by sustained energy toward the burst or the end of the murmur. This early sharp rise in amplitude of stops and nasals was likely to be due to the initial buildup of sub-glottal pressure. We excluded this initial 20% of the trajectory from the statistical analyses of the word-initial tokens because the regression model with a linear term is limited in estimating the curve shapes of amplitude changes over time. The initial 20% of the trajectory in word-medial

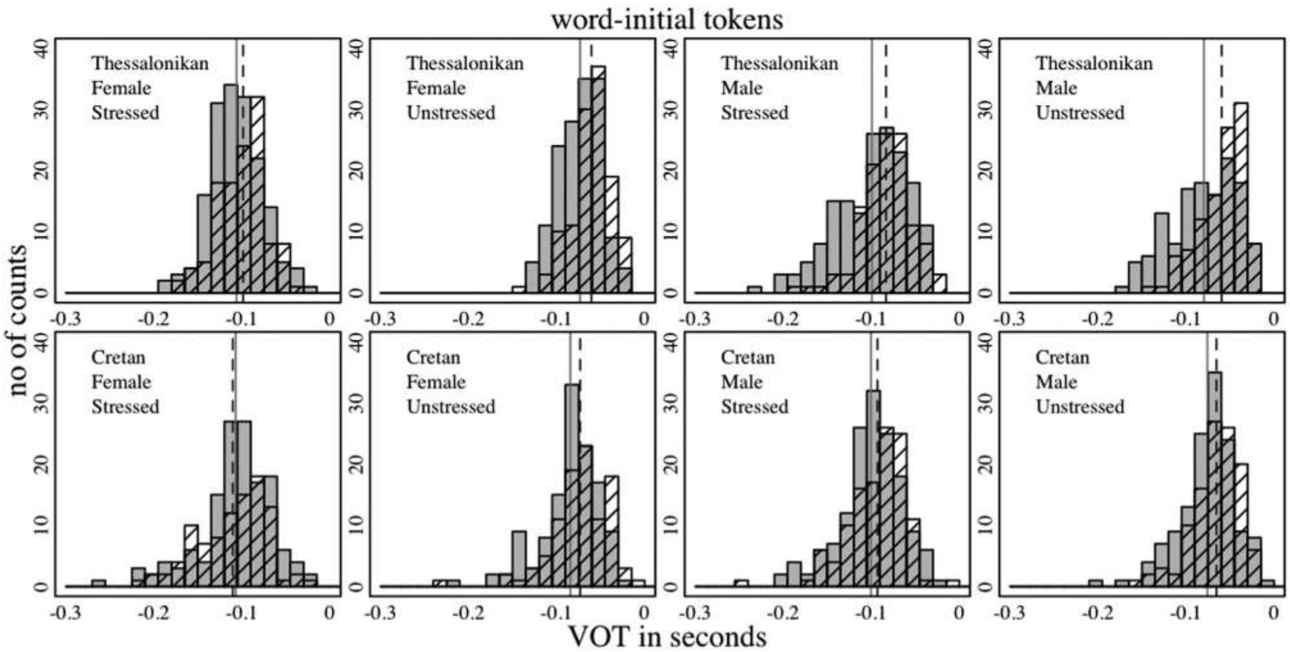

FIG. 4. Histograms of lead VOT values of voiced stops and nasal murmurs in word-initial position. Panels are separated by post-consonantal stress condition (stressed vs unstressed) and gender (male vs female) for each dialect (Thessalonikan vs Cretan).

tokens was also excluded to make the analysis procedure identical between the two prosodic conditions even though the sharp amplitude rise was not observed word-medially. Figures 8 and 9 plot the amplitude changes during voice bars and nasal murmurs predicted by the mixed-effects regression models which estimated a linear slope coefficient as a fixed effect for each speaker group separated by gender, dialect, or stress condition. Table II summarizes the coefficients of the linear slopes estimated by the regression models and the model-predicted mean values of normalized amplitudes measured at the five locations corresponding to $x = 0.2$ (i.e., near-onsets of voice bar and murmur), 0.4, 0.6, 0.8, and 1 (i.e., immediately before the burst) in Figs. 8 and 9. The interaction effects of gender, dialect, and stress condition with the linear slope terms were tested by adding each interaction term to the mixed-effects regression models.

1. *Amplitude trajectory patterns of word-initial tokens*

a. Amplitude trajectories of nasals and voiced stops. The remaining 80% of the amplitude trajectory was different for the nasal and the voiced stop productions in word-initial

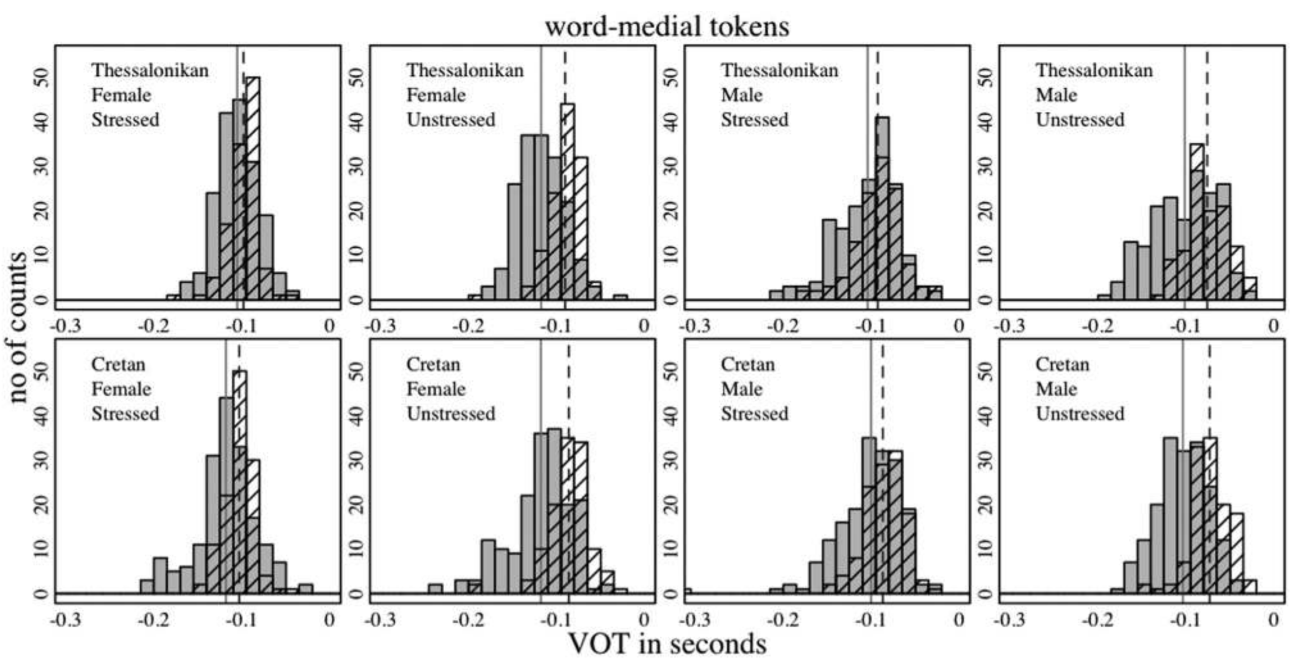

FIG. 5. Histograms of lead VOT values of voiced stops and nasal murmurs in word-medial position. Panels are separated by post-consonantal stress condition (stressed vs unstressed) and gender (male vs female) for each dialect (Thessalonikan vs Cretan).

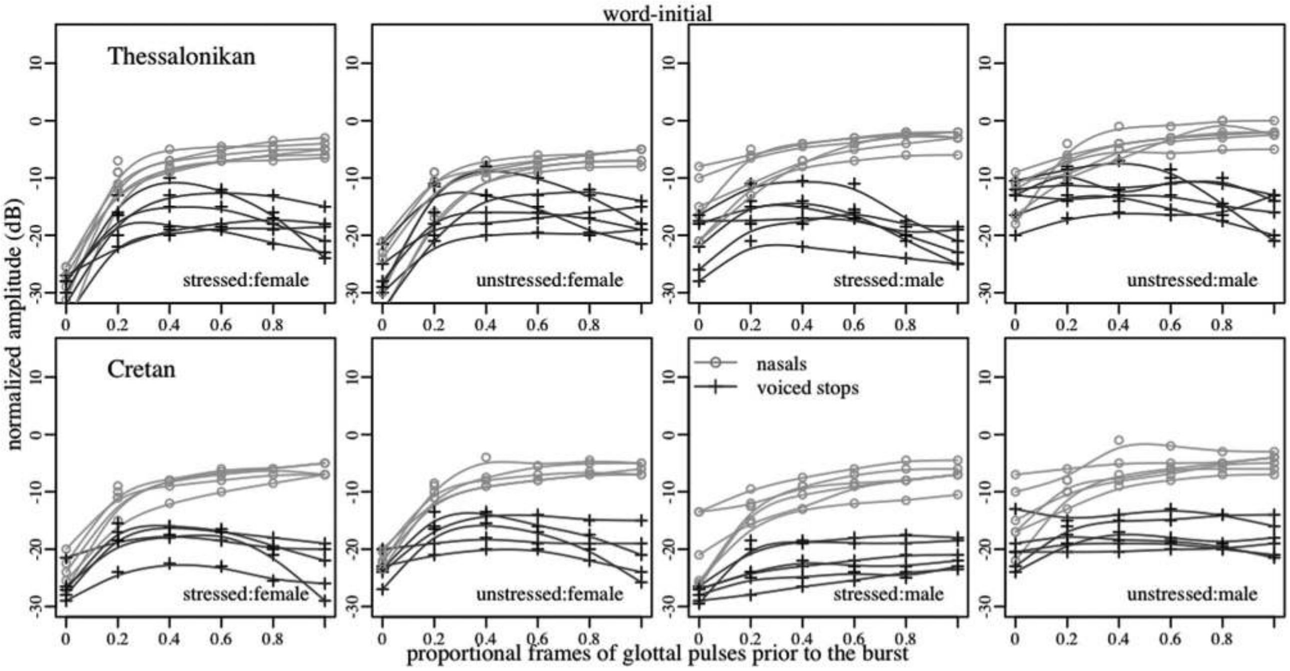

FIG. 6. Amplitude trajectories of individual speakers' nasals and voiced stops elicited in word-initial position. The curves represent connected median values of normalized amplitude relative to the amplitude of the following vowel.

position. First, the amplitude of the voice bar immediately before the burst (rightmost end of the x axis in Fig. 6) was consistently lower (mean $= -20$, s.d. $= \pm 6.8$ in dB) than that of the nasal murmur (mean $= -5.3$, s.d. $= \pm 3.3$ in dB) across dialects and stress conditions. Second, the voice bar had a falling trajectory preceded by an initial rise. As shown in Fig. 6, the different amplitude trajectory patterns of the two consonant manners in word-initial position were most clearly observed in female speakers' productions, regardless of dialects and stress conditions. According to the mixed-effects regression model of females' productions with dialects and stress conditions collapsed, the sign of the linear order coefficient for nasals was positive (*coefficient* $= 4.2$), suggesting that the linear slope of the amplitude trajectory increased as it was approaching the burst. In contrast, the sign of the linear order coefficient for voiced stops was negative (*coefficient* $= -2.43$), indicating a downward slope of the amplitude trajectory over time. Both coefficients were significant based on the deviance tests ($\chi^2 = 4.8$, $P < 0.05$ for voiced stops; $\chi^2 = 30.6$, $P < 0.001$ for nasals). Table II

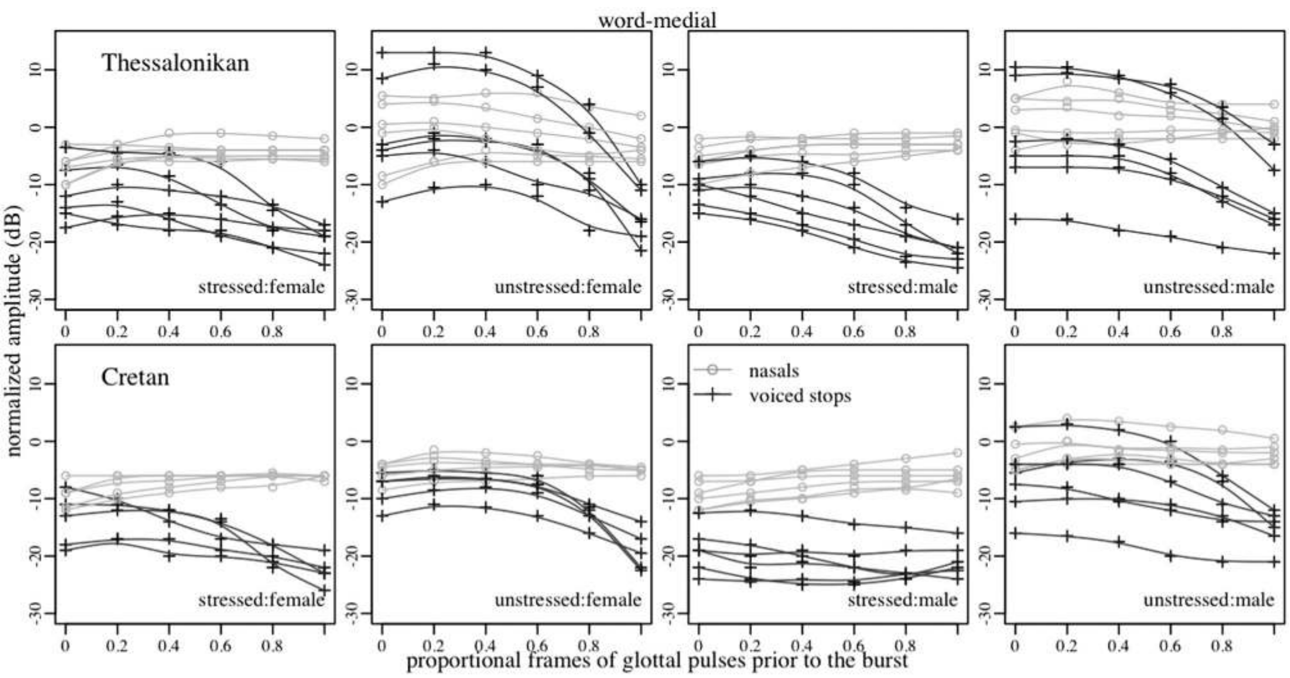

FIG. 7. Amplitude trajectories of individual speakers' nasals and voiced stops elicited in word-medial position. The curves represent connected median values of normalized amplitude relative to the amplitude of the following vowel.

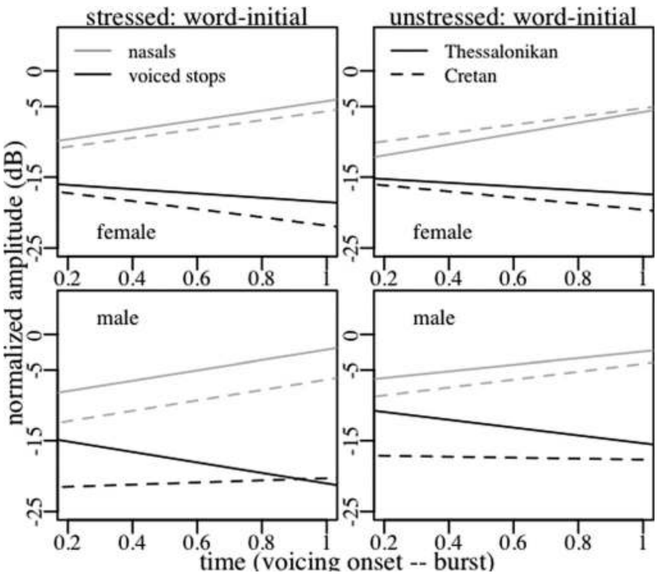

FIG. 8. Estimated trajectories of normalized amplitude from the mixed-effects regression model: Word-initial nasals and voiced stops. The panels are separated by gender and post-consonantal stress condition.

presents the outputs of the regression models of female speakers' word-initial tokens for each dialect and stress condition.

b. Amplitude trajectory differences between dialects, gender and stress conditions. Based on Figs. 6 and 7, there were individual differences in amplitude trajectories of voiced stops. Even within the same dialect and gender group, some speakers had a steep falling pattern, whereas others had a rather shallow falling pattern or maintained lower amplitude in the stops than in the nasals throughout the trajectory.

Furthermore, the degree of amplitude decrease of voiced stops seemed to vary across speakers' dialect, gender, and stress condition. With respect to dialect, Thessalonikan male

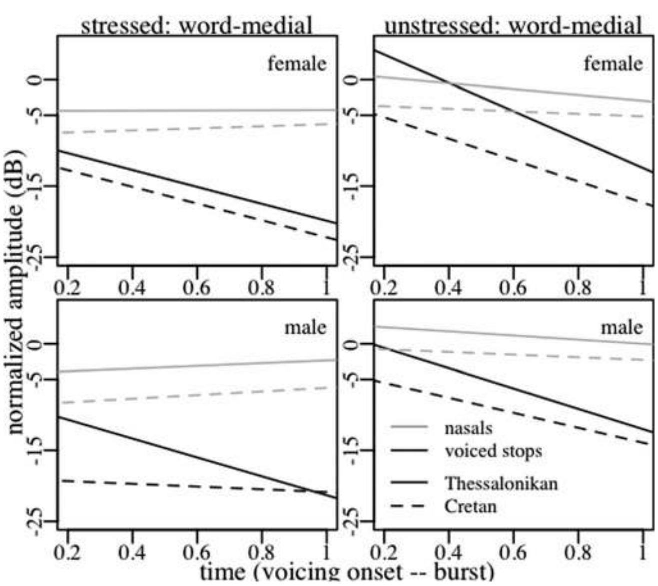

FIG. 9. Estimated trajectories of normalized amplitude from the mixed-effects regression model: Word-medial nasals and voiced stops. The panels are separated by gender and post-consonantal stress condition.

speakers' voiced stops (top right panels of Fig. 6) tended to have relatively steeper falling trajectories than Cretan male speakers' voiced stops (bottom right panels of Fig. 6). In both stress conditions, more individuals in the Cretan male group than in the Thessalonikan male group showed amplitude curves of voiced stops with onsets that were considerably lower than those of nasals. The mixed-effects models of male speakers collapsed across stress conditions supported these observations by predicting normalized amplitudes at the closure onset ($x = 0.2$ in Fig. 6) as -19.6 dB for Cretan male speakers' voiced stops (vs -10.8 dB for nasals) and as -13.0 dB for Thessalonikan male speakers' voiced stops (vs -7.3 dB for nasals). The regression models also revealed that there were statistically significant differences between the two dialects in the amplitude falls of voiced stops (deviance test: $\chi^2 = 8.39$, $P < 0.005$). A linear slope for Thessalonikan males' voiced stops (reference category of the model) was negative (*coefficient* $= -4.37$), and a coefficient difference of linear slopes between Thessalonikan and Cretan male groups was estimated as 4.73, yielding a positive but close-to-zero slope (*coefficient* $= 0.36$) for Cretan males. This small absolute coefficient of the Cretan males' linear slope suggests that Cretan male speakers' voiced stops had an almost flat amplitude trajectory, similar to the flat amplitude slope of nasals as shown in Fig. 8 (dashed lines in bottom panels). With amplitude fall absent, Cretan male speakers' voiced stops were differentiated from nasals by their overall lower amplitude. The flat linear slope and low amplitude level estimated from the Cretan males' voiced stop model suggest that these voiced stops were produced without prenasality. The results of the mixed-effects models for the nasals by male speakers of both dialects were similar to those of the female speakers described in the preceding text.

The degrees of amplitude decrease in voiced stops also differed between male and female Cretan speakers. As shown in Fig. 6 (bottom panels), Cretan male speakers' patterns were distinguished from those of Cretan female speakers (and Thessalonikan speakers) in that the amplitude trajectories for the males' voiced stops were level across subjects, and there were no individual trajectories with a noticeable amplitude decrease. This observation was supported by the output of regression models for Cretan speakers' voiced stops in which linear slope terms were significantly different between the two gender groups (deviance test: $\chi^2 = 7.48$, $P < 0.05$). The linear slope coefficient for Cretan female speakers' voiced stops (reference category of the model) was negative (*coefficient* $= -3.2$), and the linear coefficient for Cretan male speakers was positive (*coefficient* $= 0.34$) when calculated by the coefficient difference of gender groups from the reference group (*interaction coefficient* $= 3.54$).

As for the effect of stress conditions, the linear slopes of amplitude trajectories significantly differed between unstressed and stressed syllables only in Cretan males' voiced stops (deviance test: $\chi^2 = 7.89$, $P < 0.005$). More importantly, however, both the stressed and unstressed productions of Cretan males differed from those of the other speakers in having linear slopes without amplitude falls.

TABLE II. Estimated linear slopes by the mixed-effects regression models of the voiced stops and nasals produced by Thessalonikan and Cretan speakers: Bold indicates $P < 0.05$ based on deviance tests. Mean values of normalized amplitudes (in dB) at five normalized time points (as in Figs. 8 and 9) were calculated based on the model predictions.

			Mean dB at $x = 0.2$	Mean dB at $x = 0.4$	Mean dB at $x = 0.6$	Mean dB at $x = 0.8$	Mean dB at $x = 1$ (immediately before the burst)	Linear slope estimate
A. Word-initial nasals								
Female	Thessalonikan	Stressed	−9.64	−8.29	−6.93	−5.58	−4.23	**4.28**
		Unstressed	−11.87	−10.34	−8.82	−7.3	−5.77	**4.86**
	Cretan	Stressed	−10.66	−9.4	−8.15	−6.89	−5.63	**3.98**
		Unstressed	−9.91	−8.74	−7.56	−6.39	−5.21	**3.71**
Male	Thessalonikan	Stressed	−7.88	−6.42	−4.97	−3.51	−2.06	**4.61**
		Unstressed	−6.2	−5.23	−4.26	−3.28	−2.31	**2.94**
	Cretan	Stressed	−12.37	−10.89	−9.41	−7.93	−6.45	**4.66**
		Unstressed	−8.79	−7.67	−6.55	−5.43	−4.31	**3.53**
B. Word-initial voiced stops								
Female	Thessalonikan	Stressed	−16.34	−16.86	−17.38	−17.9	−18.43	−1.92
		Unstressed	−15.34	−15.85	−16.37	−16.88	−17.39	−1.67
	Cretan	Stressed	−17.08	−18.24	−19.4	−20.57	−21.73	**−3.61**
		Unstressed	−16.24	−17.1	−17.96	−18.83	−19.69	**−2.73**
Male	Thessalonikan	Stressed	−14.68	−16.29	−17.89	−19.49	−21.1	**−4.7**
		Unstressed	−10.05	−11.51	−12.97	−14.43	−15.89	**−3.5**
	Cretan	Stressed	−21.25	−20.97	−20.68	−20.4	−20.12	**0.96**
		Unstressed	−17.33	−17.48	−17.62	−17.77	−17.91	−0.43
C. Word-medial nasals								
Female	Thessalonikan	Stressed	−4.36	−4.33	−4.31	−4.29	−4.26	0.07
		Unstressed	0.34	−0.48	−1.3	−2.12	−2.94	**−2.6**
	Cretan	Stressed	−7.32	−7.04	−6.77	−6.49	−6.22	0.93
		Unstressed	−3.64	−4.02	−4.39	−4.77	−5.15	−1.12
Male	Thessalonikan	Stressed	−3.79	−3.43	−3.06	−2.69	−2.32	**1.21**
		Unstressed	2.03	1.5	0.97	0.45	−0.08	**−1.85**
	Cretan	Stressed	−8.26	−7.74	−7.23	−6.71	−6.2	**1.63**
		Unstressed	−0.74	−1.12	−1.5	−1.88	−2.26	**−1.18**
D. Word-medial voiced stops								
Female	Thessalonikan	stressed	−10.32	−12.7	−15.09	−17.48	−19.87	**−7.56**
		Unstressed	3.57	−0.43	−4.43	−8.44	−12.44	**−12.65**
	Cretan	Stressed	−12.39	−14.8	−17.21	−19.61	−22.02	**−7.47**
		Unstressed	−5.19	−8.31	−11.43	−14.55	−17.67	**−9.53**
Male	Thessalonikan	stressed	−10.59	−13.28	−15.97	−18.65	−21.34	**−8.44**
		Unstressed	−0.32	−3.2	−6.09	−8.97	−11.85	**−9.05**
	Cretan	Stressed	−19.05	−19.46	−19.88	−20.29	−20.71	−1.22
		Unstressed	−5.28	−7.41	−9.55	−11.68	−13.82	**−6.67**

2. Amplitude trajectory patterns of word-medial tokens

a. Amplitude trajectories of nasals and voiced stops. Word-medially, an abrupt amplitude rise for the initial 20% of the trajectory was not observed. Consequently, the amplitude of the nasal murmur was level throughout the trajectory (Fig. 7). Moreover, the amplitude of the voice bar in the Thessalonikan speakers (male and female) and the Cretan female speaker gradually decreased over time, resulting in lower amplitude immediately before the burst for the voiced stops than for the nasals. While individuals in each group differed in the overall amplitude levels of the voiced stops as observed in Fig. 7, this downward trend was observed across speakers. This consistently decreasing amplitude trajectories for the word-medial voiced stops across Thessalonikan and Cretan (for female speakers only) dialects and two stress conditions support the claim that Greek voiced stops tend to be more consistently prenasalized in word-medial position. The regression models of female speakers' word-medial tokens collapsed across dialects and stress conditions showed results similar to those of word-initial tokens. The word-medial productions of voiced stops had a significant negative linear slope ($coefficient = -9.37$). The absolute value of this linear slope coefficient was greater than that of the word-initial model, suggesting that the amplitude curves had a steeper downtrend in word-medial voiced than in word-initial position (see Fig. 9 for the model fits of the word-medial models in comparison with Fig. 8 for the word-initial models). The model outputs of the female speakers' word-medial nasals were also similar to those of the word-initial nasal tokens in that nasal consonants lacked steep falling amplitude trajectories (*linear slope coefficient* = −0.73).

Similar to word-initial voiced stops, the amplitude trajectories of male speakers' word-medial voiced stops were different between Thessalonikan and Crete dialects, although this difference was observed only for voiced stops of stressed syllables. Cretan male speakers' voiced stops of stressed syllables stood out by having the least clear evidence of a downward trend in their voice bars (see bottom right panels in Fig. 7). Instead the amplitude of the voice bar in these voiced stops of stressed syllables remained level, albeit at a lower level than that of the nasal murmur. The mixed-effects regression model of males' voiced stops of stressed syllables estimated significantly different slope coefficients for each dialect (deviance test: $\chi^2 = 20.5$, $P < 0.001$), yielding slope coefficients of −1.21 for Cretan dialect and −8.44 for Thessalonikan dialect. This dialect effect on the linear slope was not significant in voiced stops of unstressed syllables, as Cretan male speakers' voiced stops of unstressed syllables have significantly steeper amplitude decreases (*slope coefficient* = −6.67) than those of stressed syllables (deviance test: $\chi^2 = 122.8$, $P < 0.001$).

It is noted that in word-medial position, there was a consistent influence of stress on the overall amplitude level for both the voice bar and nasal murmur. The amplitude level was higher before unstressed vowels than before stressed vowels. This was due to the lower amplitude levels of unstressed vowels, each of which was the denominator in the amplitude normalization formula. In the unstressed vowel conditions of Thessalonikan speakers' voiced stops (top panels of Fig. 7), the speakers who produced very high amplitudes for the voiced stops produced unstressed vowels with very weak energy. While the current normalization formula is limited in that it prevents us from discussing a true effect of post-consonantal stress on the overall amplitude level, the focus of the study is more on the direction and degree of the linear slope in the target consonants.

IV. DISCUSSION

Prenasalized stops involve complex acoustics as a result of the combination of oral and nasal airflow and the precise timing of the gestures involved. Because prenasalization is a gradient phenomenon that is difficult to study, only a few studies have reported data on the acoustics of prenasalized stops acoustics (e.g., Burton *et al.*, 1992). The present study was designed to add to this literature by examining the prenasalization of voiced stops in two Greek dialects (Thessalonikan and Cretan) using duration and amplitude measures.

There is a long history of documenting the variation in production of Greek voiced stops. Much of this history is concerned with the effect of sociolinguistic factors, such as style of speech and speaker characteristics, on the realization of voiced stops as oral or prenasalized (e.g., Arvaniti and Joseph, 2000; Granqvist, 1997). A problem with previous studies, however, is that while they acknowledge that voiced stops are best described in terms of a continuous scale from full sequences of nasal/stop clusters to oral voiced stops, voiced stops are categorized as prenasalized or oral using a transcription analysis. We know from several studies that while transcription is an ecologically valid tool, it has a number of limitations that warrant the use of more objective research tools, such as the use of statistical modeling or articulatory instrumentation.

In this paper, we chose not to use a categorical approach to categorize voiced stops as either prenasalized or oral voiced stops. Instead we attempted to quantify the gradient idiolectal variability in voiced stop production and to draw inferences about the general effects of speaker dialect, age, and gender as well as the role of stress location and prosodic position on how voiced stops were acoustically realized. Using this methodology, we replicated the results of earlier transcription-based studies that found that prenasalization of Greek voiced stops was influenced by a number of factors, such as regional dialect, gender, stress, and word position (e.g., Arvaniti and Joseph, 2000; Granqvist, 1997).

Similar to previous studies in other languages and despite powerful statistical probing, we found that the durational characteristics of Greek voiced stops did not differentiate them from nasals. Although voiced stops tended to be slightly longer than nasals in both (the Thessalonikan and Cretan) dialects, their duration distributions showed a large overlap. Perhaps one explanation for the absence of large durational differences is that target consonant onsets might have been partially devoiced in the utterance initial position, and therefore the acoustic measurement did not represent the entire durations of the targets.

Our amplitude analyses were more successful at capturing the prenasalization characteristics present in Greek voiced stops, while also differentiating voiced stops from nasals. The amplitude trajectories of Greek voiced stops showed that voiced stops started with an amplitude level comparable to that of nasals and ended with an amplitude that was lower than the nasals', which is a characteristic feature of prenasalized stops in other languages as well (Burton *et al.*, 1992; Chan and Ren, 1987). Moreover, this downward trend of amplitude was stronger in word-medial position than in word-initial position in Greek.

We observed considerable individual differences across speakers in the amplitude trajectories of voiced stops. While some speakers produced voiced stops beginning with amplitude as high as that of nasals followed by a steep amplitude decrease (a clear indication of prenasalization), others produced voiced stops with a shallow amplitude decrease. Furthermore, the individual differences converged to vary as a complex function of dialect, gender, and stress condition. Acoustic evidence of at least some prenasalization in voiced stops was observed consistently for female speakers of both dialects and for Thessalonikan male speakers in both stress conditions and both word positions. By contrast, Cretan male speakers tended to produce voiced stops with low-level amplitude throughout the voice bar in both word-initial and word-medial contexts in stressed syllables. This pattern of sustained low amplitude trajectory is reminiscent of that of oral voiced stops in Moru (Burton *et al.*, 1992), suggesting that Cretan male speakers' voiced stops were not prenasalized in these contexts. This finding supports previous studies on Cretan phonology, which reported that Cretan speakers produced voiced stops without prenasalization according to impressionistic judgment (e.g., Contossopoulos, 2001; Granqvist, 1997).

Our observations concerning the effect of stress on prenasalization were also consistent with earlier research. Granqvist (1997) reported that while prenasalized voiced stops were rarely observed in Cretan speakers' word-medial productions, when prenasalization was observed, it was more likely to be on voiced stops in unstressed syllables. We observed a similar result. In addition, our study revealed gender differences in that female Cretan speakers were more likely to produce prevoiced stops with prenasalization than were male speakers in both word-initial and word-medial position.

In spite of statistically significant effects of regional dialect, gender, and stress, it should be noted that individual differences were ubiquitous. Furthermore, speakers' age was not a significant factor in explaining individual variability. We speculate that these individual differences in producing voiced stops that we observed are due to idiolects or are related to speakers' attitudes toward the task as discussed in the following text.

The present study also showed that both male and female speakers from the Thessaloniki region produced voiced stops with prenasalization even in word-initial position. This was surprising for several reasons. Previous studies have shown that prenasalized variants are not found word-initially in any Greek dialect (except Cypriot), and in fact they are completely absent in some Greek dialects, for example Cretan (Contossopoulos, 2001; Mirambel, 1959; Newton, 1972). It should be noted, however, that previous studies did not make instrumental measurements of prenasalization in voiced stops and that prenasalization can be difficult to assess on the basis of perceptual analysis alone. Our study utilized dynamic acoustic measures capable of capturing subtle differences among tokens in degree of nasality, ranging from those with a very weak nasal onset to those with an intense preceding nasal segment. It would be very interesting in future work to examine whether Greek listeners are able to distinguish such gradient differences using a technique such as visual analogue scaling (e.g., Massaro and Cohen, 1983) and/or eye-tracking (e.g., McMurray *et al.*, 2003). Articulatory research using a nasometer or a laryngograph to quantify prenasalization in voiced stops of Greek dialect speakers is also needed.

A number of additional factors may have also influenced our results of dialectal variations in voiced stop realization. These include speakers' education level, elicitation method, and further regional dialectal difference in northern Greek. First, the relatively high level of education in the participants of our study might have contributed to the presence of prenasalization in the productions of prenasalized voiced stops in word-initial position; all speakers had at least a high-school diploma, and the majority of them had a university degree. As previous studies have found (Arvaniti and Joseph, 2000; Charalambopoulos *et al.* 1992; Pagoni, 1989), more educated speakers tend to use a larger number of prenasalized tokens than less educated speakers due to the high prestige associated with prenasalized stops. The prenasalized variant of voiced stops is the prescribed pronunciation in modern Greek grammars (which is likely also related to the influence of spelling), and it is the variant that emerges in slow, careful speech.

A second factor that may have biased our results is the type of elicitation task. Unlike the informal interviews used by Arvaniti and Joseph (2000), the data presented in this study were elicited via a careful reading task. It is possible that at least to some extent, prenasalized tokens even in word-initial position were triggered by the subsequent influence of spelling on pronunciation. It is noteworthy that this elicitation method did not bias Cretan male speakers toward the prenasalized variant of voiced stops even though voiced stops are spelled the same way in both dialects.

Finally, the evidence of prenasalized variants of voiced stops among Thessalonikan speakers could reflect a dialectal difference between Thessaloniki and Athens. As Arvaniti and Joseph (2000) themselves point out "our impression as speakers of Greek, as well as that of other Greek linguists, is that [oral voiced stops are] far less prevalent in Thessaloniki than in Athens" (p. 11). The possibility of a dialectal difference in this respect and the influence of linguistic factors, such as education, social class, and elicitation method on prenasalization need to be addressed in future research.

The evidence of dialectal variation in voiced stop productions in Greek may also have interesting implications for acquisition. In particular, it would be of interest to examine the acquisition of voiced stops in the Cretan dialect. Several studies (Kong *et al.*, 2007; Okalidou *et al.*, 2010) have shown relatively early acquisition of voiced stops in dialects of Greek with prenasalization of voiced stops. Kong *et al.* (2007) found that many productions of so-called "voiced" stops by children were, in fact, fully nasalized. Kong and colleagues suggested that children use prenasalization to overcome the articulatory difficulty of maintaining voicing during stop closure by using nasality to vent air pressure during closure. If prenasalization of voiced stops is less widespread in the Cretan dialect, it may be the case that adult speakers do not accept these nasalized stops as "correct." Thus we may see differences in acquisition patterns of voiced stops in Greek depending on the dialect that children are speaking. This area needs to be addressed in future research.

In conclusion, this study described a methodology for quantifying phonetic variation in Greek /b, d, ɡ/ and also examined how this variation is influenced by both linguistic and non-linguistic factors, such as stress and dialect. This method will be useful for examining differences in the realization of voicing contrasts in other dialects and languages where prenasalization has been observed, such as Taiwanese. These results are also of interest in that within-dialect gender differences were observed, suggesting that research on phonetic dialectal differences needs to consider socio-indexical influences as well as linguistic influences.

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APPENDIX: LIST OF STIMULI

	Word-initial		Word-medial	
	Stressed	Unstressed	Stressed	Unstressed
/na/	*νάνι* /ˈ**na**ni/ "*baby word for sleep*"	*ναρκώνω* /**na**ˈɾkono/ "*sedate*"	*φανάρι* /faˈ**na**ɾi/ "*traffic light*"	*βελόνα* /veˈlo**na**/ "needle"
/ne/	*νεύρο* /ˈ**ne**vɾo/ "*nerve*"	*νερό* /**ne**ˈɾo/ "*water*"	*πανέρι* /paˈ**ne**ɾi/ "*basket*"	*σύννεφο* /ˈsi**ne**fo/ "*cloud*"
/ni/	*νίκη* /ˈ**ni**ki/ "*victory*"	*νυστάζω* /**ni**ˈstazo/ "*I feel sleepy*"	*μηχανή* /mixaˈ**ni**/ "*machine*"	*ζώνη* /ˈzo**ni**/ "*zone, belt*"
/no/	*νότος* /ˈ**no**tos/ "*South*"	*νομίζω* /**no**ˈmizo/ "*I think*"	*κανόνι* /kaˈ**no**ni/ "*cannon*"	*κόκκινο* /ˈkoki**no**/ "*red*"
/nu/	*νούμερο* /ˈ**nu**meɾo/ "*number*"	*νουβέλα* /**nu**ˈvela/ "*short story*"	*καινούρια* /keˈ**nu**ɾia/ "*new*"	*κάνουμε* /ˈka**nu**me/ "*we are doing*"
/ma/	*μάγκες* /ˈ**ma**ges/ "*macho guys*"	*μαγκιές* /**ma**ˈges/ "*acts of macho guys*"	*κιμά* /kiˈ**ma**/ "*ground meat (accus.)*"	*γράμμα* /ˈɣɾa**ma**/ "*letter*"
/me/	*μένω* /ˈ**me**no/ "*I stay*"	*μετά* /**me**ˈta/ "*after*"	*κομμένο* /koˈ**me**no/ "*cut (adj.)*"	*κάμερα* /ˈka**me**ɾa/ "*camera*"
/mi/	*μήνυμα* /ˈ**mi**nima/ "*message*"	*μηχανή* /**mi**xaˈni/ "*machine*"	*κομήτης* /koˈ**mi**tis/ "*comet*"	*νόμισα* /ˈno**mi**sa/ "*I thought*"
/mo/	*μόνιμος* /ˈ**mo**nimos/ "*permanent*"	*μοντέλο* /**mo**ˈdelo/ "*model*"	*χειμώνας* /xiˈ**mo**nas/ "*winter*"	*γάμος* /ˈɣa**mo**s/ "*wedding*"
/mu/	*μούμια* /ˈ**mu**mia/ "*mummy*"	*μουγκός* /**mu**ˈgos/ "*mute*"	*νομού* /noˈ**mu**/ "*prefecture (gen.)*"	*τόμου* /ˈto**mu**/ "*volume (gen.)*"
/ba/	*μπάλα* /ˈ**ba**la/ "*ball*"	*μπαλόνι* /**ba**ˈloni/ "*balloon*"	*τσιμπά* /tsiˈ**ba**/ "*he/she/it pinches*"	*λάμπα* /ˈla**ba**/ "*bulb, lamp*"
/be/	*μπαίνω* /ˈ**be**no/ "*I enter*"	*μπερδεύω* /**be**ɾˈðevo/ "*I confuse*"	*τεμπέλης* /teˈ**be**lis/ "*lazy*"	*κάμπε* /ˈka**be**/ "*plain (voc.)*"
/bi/	*μπύρα* /ˈ**bi**ɾa/ "*beer*"	*μπισκότο* /**bi**ˈskoto/ "*biscuit*"	*τσαμπί* /tsaˈ**bi**/ "*bunch (of grapes)*"	Τ*έμπη* /ˈte**bi**/ "*place name*"
/bo/	*μπότες* /ˈ**bo**tes/ "*boots*"	*μπορέσω* /**bo**ˈɾeso/ "*I will be able to*"	*σκαμπό* /skaˈ**bo**/ "*footstool*"	*κάμπο* /ˈka**bo**/ "*plain (accus.)*"
/bu/	*μπούτι* /ˈ**bu**ti/ "*thigh*"	*μπουκάλι* /**bu**ˈkali/ "*bottle*"	*ταμπού* /taˈ**bu**/ "*taboo*"	*κάμπου* /ˈka**bu**/ "*plain (gen.)*"
/da/	*ντάμα* /ˈ**da**ma/ "*queen of hearts*"	*νταλίκα* /**da**ˈlika/ "*truck*"	*λιοντάρι* /lioˈ**da**ɾi/ "*lion*"	*πάντα* /ˈpa**da**/ "*always*"
/de/	*ντέφι* /ˈ**de**fi/ "*tambourine*"	*ντεμπούτο* /**de**ˈbuto/ "*first professional appearance*"	*μαντεύω* /maˈ**de**vo/ "*I guess*"	*πάντες* /ˈpa**de**s/ "*everyone*"
/di/	*ντύνει* /ˈ**di**ni/ "*he/she dresses*"	*ντιβάνι* /**di**ˈvani/ "*type of bed*"	*ποντίκι* /poˈ**di**ki/ "*mouse*"	*κόντυνε* /ˈko**di**ne/ "*he/she/it shortened*"
/do/	*ντόπιος* /ˈ**do**pios/ "*indigenous*"	*ντομάτα* /**do**ˈmata/ "*tomato*"	*μουντός* /muˈ**do**s/ "*dim (masc.)*"	*πόντος* /ˈpo**do**s/ "*point*"
/du/	*ντούκου* /ˈ**du**ku/ "*(pay) in cash; disregard an important matter*"	*ντουλάπα* /**du**ˈlapa/ "*wardrobe*"	*φουντούκι* /fuˈ**du**ki/ "*hazelnut*"	*πόντου* /ˈpo**du**/ "*point (gen.)*"
/ga/	*γκάζι* /ˈ**ga**zi/ "*accelerator; gas*"	*γκαρίζει* /**ga**ˈɾizi/ "*bray, yell*"	*φεγγάρι* /feˈ**ga**ɾi/ "*moon*"	*τίγκα* /ˈti**ga**/ "*full up*"
/ge/	*γκέμια* /ˈ**ge**mia/ "*bit reins*"	Not elicited	*μαγκεύει* /maˈ**ge**vi/ "*starts acting macho*"	*άγγελος* /ˈa**ge**los/ "*angel*"
/gi/	*γκίνια* /ˈ**gi**nia/ "*bad luck*"	*γκισέ* /**gi**ˈse/ "*cashier's counter*"	*πουγγί* /puˈ**gi**/ "*stock-purse*"	*πάγκοι* /ˈpa**gi**/ "*counters*"
/go/	*γκολ* /ˈ**go**l/ "*shot on goal*"	*γκοφρέτα* /**go**ˈfɾeta/ "*type of snack*"	*ταγκό* /taˈ**go**/ "*tango dance*"	*πάγκος* /ˈpa**go**s/ "*counter*"
/gu/	*γκούντα* /ˈ**gu**da/ "*type of cheese*"	*γκουρού* /**gu**ˈɾu/ "*guru*"	*μαγκούρα* /maˈ**gu**ɾa/ "*walking stick*"	*καγκουρό* /ka**gu**ˈɾo/ "*kangaroo*"

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