# VOICELESS GREEK VOWELS

Marianna Kaimaki

University of Cambridge
mk724@cam.ac.uk

## ABSTRACT

Previous studies on the acoustic properties of Greek vowels have indicated that they may have voiceless realisations in certain phonological contexts. Researchers have suggested that such devoicing is restricted to the high vowels /i/ and /u/ [7], [10]. Analysis of production data from 12 native Greek speakers suggests that devoicing is not restricted to the high vowels but that other vowels can also be produced voiceless in the appropriate phonological environment. The data indicates that voiceless vowels can be found utterance-finally after voiceless consonants, under two conditions: (1) the vowel must be unstressed and (2) the intonation contour associated with the word in which the vowel occurs must be falling (utterance-final voiceless vowels do not co-occur with final rising contours).

**Keywords**: vowels, Greek, voiceless, intonation.

## 1. INTRODUCTION

Modern Greek has a five vowel system /i, ɛ, ɐ, ɔ, u/. Their phonetic realisation in the vowel space exhibits considerable variability in spontaneous speech even to the extent of instances of overlap between phonologically distinct vowels (see [11]). Despite the fact that vowels are voiced by default in Greek, a number of studies have reported that under certain phonological circumstances (e.g. in an unstressed position and/or in the vicinity of voiceless consonants) some vowels may lenite or change some of their characteristics (e.g. peripheral vowels may become central [4]). Changes in the phonetic realisation of vowels is not restricted to changes in their formant values but it also extends to changes in their formant structure. In Standard Modern Greek as spoken in Athens, for instance, the high vowels /i/ and /u/ can be devoiced or even elided in unstressed syllables [1]. Research so far (e.g. [6], [10], [7]) suggests that the vowels which undergo this kind of lenition or deletion are the close vowels /i/ and /u/. Arvaniti in her article about Standard Modern Greek [1] mentions this process of devoicing/elision of the two high vowels noting that the reasons for the devoicing are not clear but seem to be related to stress patterns as well as the phonetic environment (presence of voiceless consonants) [1].

We propose that the process of lenition or deletion is not limited to high vowels but in certain phonological environments all Greek vowels may undergo changes in their distinctive characteristics and more specifically their voicing. In addition, there appears to be an association between final voicelessness and the overall intonation contour of the utterance: final falling intonation appears to facilitate the occurrence of voiceless realisations. Determining the validity of this hypothesis is of particular linguistic interest as voiceless vowels are typologically rather rare and the study of their distribution potentially sheds light on broader questions concerning the phonetics/phonology interface.

## 2. EXPERIMENT

### *2.1 Speakers*

Recordings were made of twelve native speakers of Greek (6 males and 6 females with ages ranging from 20 to 65). All were from the city of Thessaloniki and spoke the variety native to the city, which is Standard Modern Greek (see [12] for a classification of Greek dialects). All speakers were educated at University level, none of them were monolingual but none of them were simultaneous bilinguals either. None of the speakers presented or reported any speech or hearing problems.

### *2.2 Materials*

Sentences were constructed which included words containing the vowels /i, ɛ, ɐ, ɔ, u/, in an unstressed utterance-final position. The phonetic environment for every vowel was varied so as to represent the range of Greek voiceless consonants (i.e. single plosives and fricatives but excluding affricates or consonant clusters). Only voiceless consonants were included in the dataset to maximise the possibility of occurrence of voiceless vowels, as this environment (after voiceless consonants, utterance final) has been found to contribute to the high Greek vowels /i/ and /u/ being produced as whispered [7]. All final words were tri-syllabic and had the same accentual pattern, with stress falling on the antepenultimate syllable. Table 1 shows the words used.

**Table 1: Words used arranged by vowel quality of final vowel (first row) and type of consonant preceding them (first column)**

| | i | ɛ | ɐ | ɔ | u |
|---|---|---|---|---|---|
| **c,k** | ˈpsɛftici<br>fake | ˈɛnicɛ<br>tenant | ˈpɛɾðikɐ<br>grouse | ˈɐlikɔ<br>scarlet | ˈɐðiku<br>unfair |
| **p** | ˈɛfipi<br>on horseback | ˈɛlipɛ<br>was missing | ˈlɛlɐpɐ<br>great dis-truction | ˈɛndipɔ<br>typed document | ˈɛsɔpu<br>Aesop (gen) |
| **t** | ˈɐsiti<br>without grain | ˈxɐnɛtɛ<br>lose (2nd pl) | ˈɐnɛtɐ<br>relaxing | ˈɐlitɔ<br>unsolved | ˈɛnɐtu<br>ninth (gen) |
| **f** | ˈɐvɐfi<br>unpainted | ˈɛvɐfɛ<br>was painting | ˈɛɣɾɐfɐ<br>was writing | ˈɐcɛfɔ<br>sad | ˈɐɣɾɐfu<br>unwritten (gen) |
| **θ** | ˈɐvɐθi<br>shallow | ˈɐmɐθɛ<br>ignorant (voc) | ˈɛɲɔθɐ<br>was feeling (1st sing) | ˈɐniθɔ<br>dill | ˈɐniθu<br>dill (gen) |
| **s** | ˈcɛnɔsi<br>void | ˈɐfisɛ<br>let go | ˈɛnɔsɐ<br>joined (1st sing) | ˈɐnisɔ<br>uneven | ˈɐvisu<br>abyss (gen) |
| **ç,x** | ˈɛnɔçi<br>guilty | ˈɛlɐçɛ<br>happened | ˈɛvixɐ<br>was coughing (1st sing) | ˈɛksɔxɔ<br>spectacular | ˈisixu<br>quiet (gen) |

Participants produced the words shown in Table 1, in 2 carrier sentences, controlling for rising and falling pitch; the two carrier sentences used were:

(1) *Πώς σου είπε η Μαριάννα πως γράφεται το X;*
How did Marianna tell you X is spelt?

(2) *Η Μαριάννα μου είπε να πω X.*
Marianna told me to say X.

Carrier sentence 1, a wh-question, was produced once for each phonological context + target vowel yielding 35 productions per speaker. Carrier sentence 2, a statement, was produced twice for each phonological context + target vowel yielding 70 productions per speaker. The number of repetitions varied between the two sentences as it was expected that in sentences with final falling intonation it was more likely to get productions of final voiceless vowels than in sentences with final rising intonation. The data was randomised (5 randomisations) to avoid any order effects. Each speaker produced 105 target sentences in total plus 114 dummies. Dummies were designed to be of similar syntactic structure to the stimuli (e.g. *Πόσο ήταν το κόστος;* - How much did it worth? or *Χρειαστήκαμε να πάρουμε τρείς φακούς* - We had to take three torches) so as not to stand out and affect participants' performance.

*2.3 Recordings*

Participants were recorded in a quiet room at the Aristotle University of Thessaloniki. Each speaker was recorded separately on a portable solid-state recorder (Marantz PMD660). The data was transferred on a computer using Audacity with a sampling rate of 44100Hz. Acoustic analysis was conducted using PRAAT software [5].

*2.4 Analysis*

Portions of the acoustic signal were identified for analysis first by careful listening and followed by visual inspection of the waveform and spectrogram. No acoustic measurements were made, as the aim of the experiment was to test the presence or absence of voicing in final vowels. A vowel was labelled 'voiceless' if there was no voicebar visible on the spectrogram and no percept of voicing and 'voiced' if there were regular vocal fold vibrations perceived and detected on the waveform and spectrogram.

## 3. RESULTS

*3.1 Intonation and voiceless vowels*

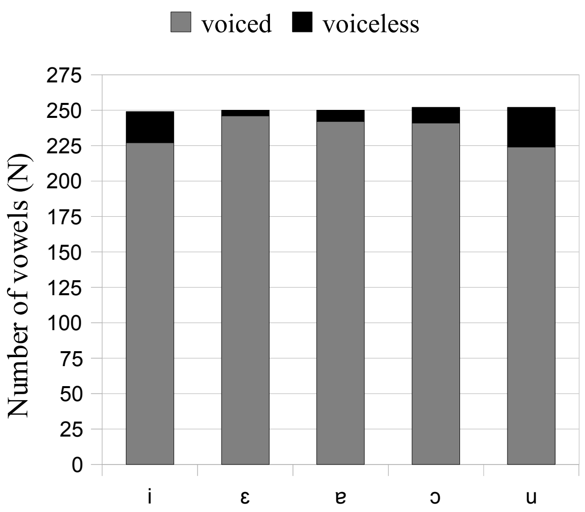
The pitch contours produced by participants were consistent for each type of sentence, with final falls for declaratives and final rises for wh- questions. The pitch contours used for the two sentences can be analysed, within the autosegmental metrical framework, as (L*+)H L- !H% for the wh-questions and L*+H H* L- L% for the declaratives (see [2] and [3] for an analysis of the Greek declaratives and wh-questions respectively). Participants produced 6% of their final vowels voiceless in the final falling pitch condition at the end of declaratives, but only voiced vowels at the end of wh-questions which were produced with final rising pitch.

*3.2 Phonetic environment of voiceless vowels*

The number of voiceless vowels encountered in the data and their distribution as to vowel quality is shown in Figure 1. Overall, there are 73 voiceless vowels out of a total of 1,253 vowels in the data. We can see that /i/ and /u/ have the highest number of voiceless instances. Voiceless tokens of /i/ account for 9% and voiceless instances of /u/ account for 11% of the total number of /i/ and /u/ vowels in the data respectively. This agrees with research done so far [7], [8] which reports that those two high vowels can be realised as voiceless. However, it is also clear that open /ɐ/ and mid /ɛ, ɔ/ vowels have also some of their instances produced with no vocal fold vibration

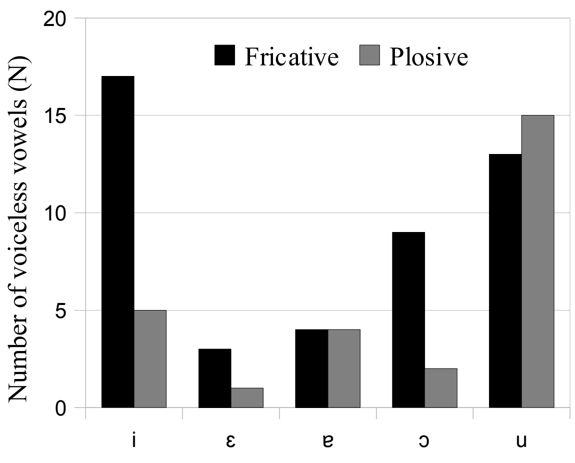
(3% of all /ɐ/ tokens, 2% of all /ɛ/ tokens and 4% of all /ɔ/ tokens).

**Figure 1: Number of voiced and voiceless vowels**




The distribution of voiceless vowels with respect to their phonetic environment is shown in Figure 2. It can be seen that both voiceless fricatives and voiceless plosives allow voiceless vowels to follow them and the manner of articulation of the preceding consonant (fricative vs plosive) appears to have an effect on the following vowel. There are more voiceless vowels after fricatives (N=45, 62% of the total voiceless tokens produced) than plosives (N=27, 38% of the total voiceless tokens produced).

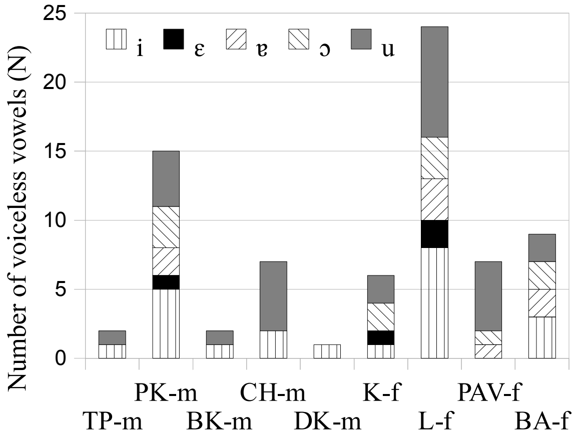
**Figure 2: Voiceless vowels produced after fricatives and plosives**




*3.3 Voiceless vowels and speaker use*

Not all speakers produced voiceless vowel tokens. Figure 3 shows the number of voiceless tokens per speaker. Nine out of 12 speakers produced voiceless vowels. In total, more males (N=6) produced voiceless vowels than females (N=3) but individual females produced more voiceless vowels than individual males.

**Figure 3 Breakdown of voiceless vowels per speaker**




Furthermore, not all speakers produced the whole range of vowels voiceless. Speakers L (female) and PK (male) are the only ones who produce voiceless tokens of the whole vowel set and they are the ones who produce the most voiceless vowels (L=24, PK=15). For the other speakers we can see that there is a pattern as to which vowels they produce voiceless first and which vowels follow. The high close vowels /i, u/ are the first that speakers produce voiceless and only if they have voiceless instances of those, do they extend their voiceless productions to the mid and open vowels. Only one speaker (PAV-f) digresses from this pattern having voiceless productions of /ɐ, ɔ, u/ but none for /i/.

We calculated a logistic regression test to determine which factors contribute to variability in voicing. We ran a model with *speaker*, *pitch* (falling/rising), *consonant* (k, p, t, f, θ, s, x), and *vowel quality* (i, ɛ, ɐ, ɔ, u) as independent factors, and the nominal variable 'voicing/voicelessness' as a response. The model was significant ($R^2$(U)=.36, $X^2$=115, p<.0001*). *Speaker* is a significant predictor ($X^2$=105.9, p<.0001*), as is *pitch* ($X^2$=59.2, p<.0001*), and *vowel quality* ($X^2$=36.7, p<.0001*). Judging by the $X^2$ values, the predictor *speaker* is the one that explains most of the variability in voicing/voicelessness in the data. That is, there is significant between-speaker variability in voicing/voicelessness of a final vowel. However, the results should be treated with caution as the sample was imbalanced with far more final voiced vowels than voiceless.

## 4. DISCUSSION

Voiceless vowels were encountered only in sentences with final falling intonation, while final vowels in sentences with rising intonation were always produced with vocal fold vibration. This finding echoes the observation by [9] that many tone and pitch accent languages fail to devoice high-toned vowels (Japanese, Cheyenne, Acoma). In the present case, one obvious way of accounting for this variability is by reference to the physiology of the vocal tract and the articulatory mechanisms for producing speech. Falling pitch is primarily accomplished by reducing the rate of vocal fold vibration. For voicelessness, however, the vocal folds are not vibrating but are instead fully abducted. The production of vowels as voiceless could then be a natural physiological consequence of the vocal folds vibrating slowly for the production of falling pitch.

Another possible explanation for the voiceless vowels encountered in the data could be their placement in the sentence. The vowels examined being sentence final, the voice quality associated with them could just be the 'side effect' of the vocal apparatus' preparation to cease producing speech. Due to the nature of the material collected for this study, which only involved capturing the acoustic energy of the speech signal, it is not possible to take all these factors into account to test the validity of any such claims.

The data also shows that final falling utterances display the whole range of voiceless vowels, with /i/ and /u/ being the first to get produced voiceless. One account explaining this phenomenon could be that this is a phonetic process, which may vary potentially depending on the vowel quality. However, as all vowels can be produced voiceless, this cannot be a sufficient explanation for the data examined. Another hypothesis could be that this is a phonological rule with wide distribution and specific locus of application. The current experiment does not provide us with all the required data that would allow us to make such a generalisation but we think that it is very unlikely that this process is phonologically motivated. The phonetic environment in which voiceless vowels are found includes all consonants in the data, with one condition: the utterance has to have a final falling intonation. Voiceless vowels are more likely to appear after voiceless fricatives rather than voiceless plosives, which indicates that the phonetic environment may be an important factor in determining the realisation of the final vowels as voiced or voiceless.

As the experiment involved different individuals and the distribution of voiceless vowels was not even across all speakers, there is also the issue of whether the realisation of voiceless vowels is related to the idiolect of the speaker. The results of the logistic regression do indicate that the production of voiceless vowels could be part of a speaker's idiolect, as speaker identity is the best predictor in the statistical model. The absence of voicing in the final Greek vowels then appears to be part of the sociophonetic variability of Greek, conditioned by word-stress and the nature of the surrounding consonants. This could have potential implications for forensic phonetics, as voiceless vowels could be a discriminant factor for speaker identity.

The results of this experiment are of particular importance as final Greek vowels may carry morphosyntactic information which is crucial for the correct interpretation of the linguistic message. A production of a voiceless vowel, may result in the neutralisation of contrast between e.g. ‘έχασα’ /ˈεχɐsɐ/ (I lost) and ‘έχασε’ /ˈεχɐsε/ (he/she lost), leading to loss of morphosyntactic information. If the vowels are realised as voiceless but the linguistic message is still perceived nevertheless, then there should be some other factor contributing in the decoding of information. This could be intonation, traces of spectral information of the vowel in the preceding consonant (see [8] for evidence of spectral coarticulation in Cypriot Greek) or the overall context.

## 5. CONCLUSIONS

In this paper we extended the existing research on the production of Greek vowels. Unlike findings reported so far, results showed that all Greek vowels (/i, ε, ɐ, ɔ, u/) can be realised as voiceless and not just the high vowels /i, u/. Furthermore, speaker and pitch were found to be significant contributors in the vowels' production as voiced or voiceless. The results of the study are anticipated to contribute to both understanding the nature of Greek vowels as well as understanding the vowel typology of natural languages.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