

# The production and perception of word-initial geminates in Cypriot Greek

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## ABSTRACT

The production and perception of word-initial geminates and singleton consonants in Cypriot Greek are investigated. Evidence from word-medial segments indicates that increased duration is the primary acoustic feature for geminates. However, it is found that Voice Onset Time (VOT) serves as a secondary acoustic cue accompanying geminate production. This cue is crucial to absolute initial stops since their duration cannot be discerned. Results of a perception experiment indicate that listeners are capable of distinguishing initial geminates and singletons, suggesting that VOT is sufficiently salient to indicate segment length.

## 1. INTRODUCTION

Geminates are commonly referred to as ‘long’ consonants since the phonetic feature most commonly associated with them is duration of articulation [1]. However, most observations regarding the acoustic correlates of geminates come from languages that have word-medial geminates, a fact which is unsurprising considering that geminates are most commonly found in this environment [2]. In fact, the acoustic features of initial geminates as they relate to production and perception have been investigated in depth for just one language, Pattani Malay [3], [4], [5], [6], [7].

As Abramson notes in [7], there are special considerations related to the phonetic realization of initial geminates. Specifically, it is observed that since voiceless stops exhibit no vocal tract excitation during their closure period, there can be “no direct signal of the relative durations of stop closures in utterance-initial position” (p. 591). Since listeners are able to correctly distinguish initial voiceless stops in this language, Abramson concludes that these segments must be produced with secondary acoustic cues that distinguish geminates and singletons, even in initial position.

It is hypothesized that Cypriot Greek speakers utilize secondary acoustic cues to indicate the length of initial segments, and that these cues are sufficient to aid in listener discrimination. To test these hypotheses, I conducted production and perception experiments involving initial geminates in Cypriot Greek. As will be shown, speakers produce initial and medial geminates and

singletons in a significantly different manner, and due to these differences in realization, listeners are able to distinguish between geminates and singletons.

## 2. PRODUCTION OF INITIAL GEMINATES

In a detailed investigation of the production of medial geminates in Cypriot Greek, Tserdanelis and Arvaniti [8] found that both duration and VOT are significantly longer for word-medial geminates than for singletons. These studies establish the phonetic identity of these segments, and provide much-needed background regarding the production of geminates and singletons in general for this language. However, the investigators did not study the production of the word-initial geminates in Cypriot Greek.

To establish that initial geminates and singletons differ as medial ones do, the VOT values for stops in these environments were measured and analyzed. Additionally, the duration of fricatives and word-medial stops were measured in order to verify that the geminate closure durations are longer than their singleton counterparts.

*Subjects:* Six native speakers of Cypriot Greek, three females and three males ranging in age from 18 to 30 served as subjects for the production study. The subjects were compensated for their time. No subjects reported speech or hearing disorders.

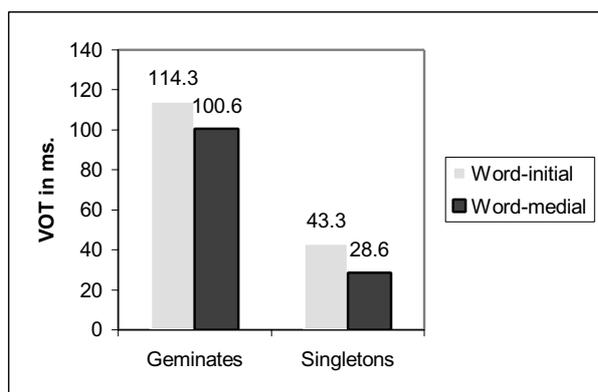
*Data:* Examples of geminates and singleton consonants were collected representing three different stops (/p/, /t/, /k/) as well as a fricative (/ʃ/). For each sound, two different environments are represented: word-initial position, as well as word-medial, intervocalic position. For each condition, three individual words were elicited. Tokens were selected with the intent of avoiding independent factors (e.g. stress) that may alter production. Each subject was recorded individually in a sound booth at the Ohio State University Department of Linguistics Laboratory. The speakers were fitted with a head-mounted, unidirectional Shure SM-10a microphone, and their speech was recorded on a Sony Digital Audio Tape (DAT) PCM-1 recorder. Subjects were asked to say token words in isolation as well as in a carrier phrase, which ends in an unstressed vowel. The elicitation list was presented three times, each time in a different random order.

*Data measurement:* The tokens that were produced in the

carrier phrase were transferred to a computer and down-sampled to 11025 Hz. For the word-medial instances of the target sounds, acoustic features that are indicators of segment duration were measured by examining spectrograms, following standard segmentation procedures.

In keeping with the findings of Tserdanelis and Arvaniti, it was found that the duration of word-medial geminate segments are significantly longer than that of singleton consonants, regardless of segment type.

The duration of the absolute word-initial stops cannot be measured, since they are voiceless (the Cypriot inventory does not include voiced stops) and thus are silent throughout their closure duration. Unlike the word-medial stops, absolute initial segments are not flanked on both sides by noise which aids in determining their duration. Therefore, voice onset time (VOT) was measured following each target consonant release. The results of these measurements are illustrated in Figure 1, which indicates the average VOT for geminate and singleton stops, according to their phonological environment. As can be clearly seen, there is a difference in VOT values not only between geminates and singletons, but also between segments in word-initial and word-medial environments.



**Figure 1:** Average VOT for geminates and singletons

The results of the VOT measurements were submitted to a repeated-measures ANOVA with three factors: Environment (word-initial or word-medial); Type (singleton or geminate); and Segment (/p/, /t/, or /k/). Of those factors, Environment was significant ( $F(1,5) = 23.04, p < .05$ ), as was Type ( $F(1,5) = 323.63, p < .05$ ); The Segment factor was not significant.

With regard to the absolute difference, for both geminates and singletons, the VOT of initial stops is about 14 ms. longer than the medial value. A simple effects analysis of Type by Environment reveals that for the class of singleton stops, there is a significant difference between the VOT values in the two environments ( $F(1,5) = 17.6, p < .05$ ). For geminate stops, the effect is also significant: ( $F(1,5) = 6.9, p < .05$ ).

### 3. PERCEPTION OF INITIAL GEMINATES

The purpose of this experiment was to determine whether speakers could correctly identify word-initial geminates and singletons, and to determine if there were any differences in successful identification rates between the different types of segments.

*Data:* Since Cypriot contains few perfect minimal pairs that contrast initial geminates and singletons, subjects were exposed to the initial syllables of words and asked to identify each word in an identification task. For example, the listeners heard the syllable [t:el], and were asked to decide if this syllable came from the Cypriot word *telaron* 'cloth frame' or *t:eliaz* 'fence in'.

The subjects were presented with examples of the geminate and singleton counterparts of four word-initial target sounds (/p/, /t/, /k/, /ʒ/), in two different phrasal environments: in a carrier phrase, such that the target sound was preceded by a vowel, and in isolation, such that the target sound was preceded by silence.

*Stimulus material:* A native Cypriot speaker was recorded saying words with the initial target segments. These recordings were then edited and used as stimuli. Words that did not contain target sounds were also collected to serve as training items for the subjects to learn the structure of the experiment.

The words selected as sources for stimuli were identified as being common and contemporary by the speaker. Furthermore, they were chosen to ensure that the initial syllable of each pair was identical, so that editing would yield a pair that was identical in all aspects except the identity of the initial segment.

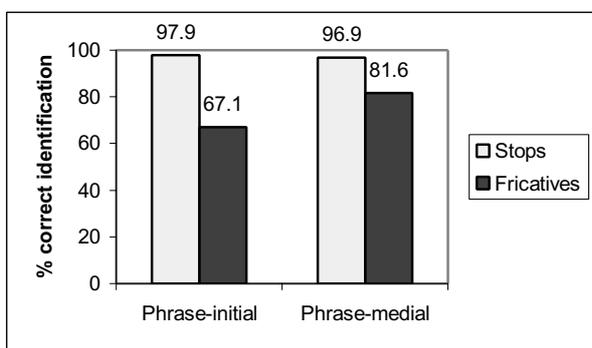
The speaker was recorded in a sound booth at the Ohio State University Department of Linguistics phonetics laboratory, using a head-mounted unidirectional Shure microphone. The tokens were recorded on a Sony Digital Audio Tape (DAT) deck. Each token was transferred to a computer and down-sampled to 11025 Hz, then edited using speech analysis software.

*Method:* The listeners were instructed to listen to each token once and to decide which word they heard. For each token they were given two possible options: the word with an initial singleton consonant, and the word with an initial geminate. Subjects were required to pick one, even if they were not entirely sure of their answer. During the experiment, the subjects marked their answers on an answer sheet by circling the word they believed they heard. The experiment lasted for approximately 15 minutes.

*Results:* Overall, listeners were able to correctly identify the category of the target sounds in over 92% of the tokens presented to them. This percentage is obtained by

averaging the responses for all listeners, across all target sounds, and for both phrase environments. The result indicates that the main hypothesis of this study is supported: listeners are able to successfully distinguish initial geminates from singletons.

The success rates for identification of segments in the two phrasal environments are illustrated in Figure 2. As can be seen, stops are correctly discerned by the listeners in both phrase-medial and phrase-initial position at a higher rate than fricatives. Across both environments, singleton and geminate stops are correctly recognized 97.4 percent of the time, while fricatives are recognized just 74.4 percent of the time.



**Figure 2:** Identification rates of word-initial geminates and singletons, in different phrasal environments

The identification percentage values were transformed to their arcsine values so as to fit the assumptions of the ANOVA model. The transformed values across all categories were submitted to a repeated-measures ANOVA with three factors: Type (fricative or stop); Category (geminate or singleton); and Environment (phrase-medial or -initial). Type was significant ( $F(1,5) = 22.2, p < .05$ ), as was Environment ( $F(1,5) = 8.1, p < .05$ ). Furthermore, the interaction between Type and Environment was also significant ( $F(1,5) = 7.2, p < .05$ ).

The identification results for phrase-initial segments were submitted to a repeated-measures ANOVA with two factors: Type (Stop or Fricative), and Category (geminate or singleton). Environment is not a factor since only phrase-initial segment identification rate is being evaluated. The results of the ANOVA indicate that only Type is significant ( $F(1,5) = 27.1, p < .05$ ). As indicated by the identification values in the graphs, it is evident that the stops are identified at a significantly higher rate than the fricatives.

Figure 2 reflects a very slight difference between the successful identification rates of stops in different environments. The results were submitted to a repeated-measures ANOVA with two factors: Category (geminate or singleton) and Environment (phrase-initial or -medial). Type is not a factor since only stops are evaluated for this test. The ANOVA reveals no significant difference

between the identification rates of stops in different environments.

#### 4. DISCUSSION

The results of the production and perception studies taken together indicate that speakers distinguish geminates and singletons in Cypriot Greek, and that these differences are salient enough for listeners to correctly identify geminates and singletons, even in absolute initial position.

Since duration of articulation cannot be discerned in absolute initial position, VOT serves as the secondary acoustic feature which is employed by speakers and listeners to distinguish the phonological length of initial stops. However, it is crucial to point out that there is the possibility that there are other acoustic cues which are responsible for distinguishing segments, even in light of Tserdanelis and Arvaniti's findings. For example, Abramson [5], [7] has identified two distinct cues, RMS amplitude and  $F_0$ , as aiding Pattani Malay listeners in identifying initial geminates; Abramson's forthcoming work investigates how these two cues work in concert to distinguish these stops. Based on these findings, it is possible that the realization of geminates in Cypriot Greek is manifested not only with increased VOT values but also with other cues, and that those cues aid the listener.

While it is unknown whether VOT is the only relevant cue other than duration which marks geminates in Cypriot, the present findings hold important implications for cross-linguistic generalizations. Specifically, the Cypriot findings suggest that there are no universals with regard to the secondary cues that accompany geminate production. Investigations of geminates in other languages have found a range of results: Lahiri and Hankamer [9] found that VOT is significantly *shorter* following geminates in Turkish (*cf.* the present results, where VOT is longer following geminates), while in Thurgovian, Kraehenmann [10] found no significant VOT differences following stop releases. Similar results were found in a pilot investigation of Leti geminates [11]. It is apparent that the realization of secondary acoustic cues is language-specific. Whether the cues can be predicted (e.g. depending upon phonetic inventory of specific languages) remains an empirical issue.

#### ACKNOWLEDGEMENTS

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