

# The scope of prominence-induced lengthening in Greek

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## ABSTRACT

It is well established that lengthening, i.e., longer duration, is one of the correlates of lexical (stress) and phrasal (accent) prominence. However, it is unclear what the scope of this lengthening is, whether it is affected differently by stress and accent, and whether it crosses prosodic boundaries. The electromagnetic articulography study of Greek reported here assesses the scope of prominence-induced lengthening as a factor of stress position (antepenultimate, penultimate, ultimate), prominence source (stress vs. accent) and boundary type (phrase vs. word boundary). Results from five speakers indicate that prominence-induced lengthening affects one continuous domain including the stressed syllable and extending both before and after that syllable. The exact scope of the effect varies with stress position, and crosses word boundaries when the stress is ultimate. Importantly, the scope of lengthening is the same regardless of the source of prominence, stress or accent. Implications for the hierarchy of prominence are discussed.

**Keywords:** stress, accent, lengthening, articulation, Greek.

## 1. INTRODUCTION

*Prominence* marks syllables within words (i.e., at the lexical level) and words within phrases (i.e., at the phrasal level) as rhythmically or conceptually salient. We refer to the sources of lexical and phrasal prominence as *stress* and *accent* respectively. Duration is one of the main correlates of prominence (e.g., acoustics: [1, 9, 22]; articulation: [4, 5, 7, 8, 12]): accented syllables are longer than unaccented stressed syllables, which are in turn longer than unaccented unstressed syllables (see [11] for an overview). However, languages differ in the extent they use duration to mark prominence. For example, in Arabic stressed syllables are longer than unstressed, but focus, and thus accent, does not further affect the duration of the stressed syllable [9]. Similarly, stressed syllables in Greek present longer articulatory movements than unstressed

syllables, regardless of their accentual status [17]. It is possible, however, that prominence-induced lengthening at the phrasal level is not controlled merely by the presence of accent, but by the type of focus that the accent denotes [18, see also 3, 13]. For instance, in German, contrastive focus has a strong lengthening effect, but broad focus does not [3, 18].

Most of the discussion on prominence-induced lengthening concerns the stressed vowel and/or syllable, and little is known about the scope of the effect, meaning the stretch of speech affected. Relevant work has mainly focused on contrastive accent, showing that the induced lengthening extends beyond the stressed syllable [e.g., 6, 20, 21, 22]. In Standard Scottish English, for instance, lengthening induced by contrastive accent affects the stressed syllable, the rhyme of the syllable immediately following the stressed one, the word-final syllable, and the word-initial segment [10]. The extent of lengthening is such that it also crosses word boundaries, affecting at least the first syllable of the following word [22, see also 23]. These findings suggest that accentual lengthening does not extend over a continuous stretch of speech, but affects multiple domains, involving both anticipatory (before the stress) and spill-over (after the stress) effects [10]. Since this evidence comes from contrastive accent, it is unclear whether the scope of prominence-induced lengthening varies with source of prominence, possibly reflecting a hierarchy of prominence (e.g., stress < non-contrastive accent < contrastive accent). Here, we use articulatory data of Greek to assess the scope of prominence-induced lengthening, whether it varies with source of prominence (stress vs. non-contrastive accent), and whether it crosses prosodic (word and/or phrase) boundaries. The relationship between prominence and boundaries has become increasingly relevant, as recent findings from Greek show that stress position affects the timing of phrase-final lengthening and boundary tones [15, 16]. Greek is a good language to examine, because it uses stress contrastively while restricting it in one of the final three syllables of the word.

## 2. METHODS

### 2.1. Participants and recording procedure

The data from 5 native speakers of standard Greek (4 female, 1 male; ages 19-31) were analysed. Participants were naïve to the purpose of the experiment, reported no speech, hearing or vision problems, and received financial compensation for their participation. A training session preceded the recording session by 1-3 days in order to familiarize the participants with the materials and the procedure. This included learning the meaning of the stimuli's made-up words and practicing the required intonation patterns.

The experimental session used an AG500 three-dimensional electromagnetic transduction device (Carstens Medizintechnik) to acquire kinematic data. Receiver coils were attached to the tongue dorsum, tongue body, tongue tip, upper lip, lower lip, upper incisor, lower incisor, jaw, left ear, right ear, and nose. Simultaneous audio recordings were performed at a sampling rate of 16 kHz.

### 2.2. Experimental design and stimuli

To examine the effect of stress position on the scope of prominence-induced lengthening, the test words were stressed on one of the following syllables: 1) the antepenult (S1), 2) the penult (S2), or 3) the ultima (S3), covering all possible stress positions in Greek. In order to reduce any segmental effect, the made-up words /'mēmimē/, /mē'mimē/, and /mēmi'mē/ were used. Two sources of prominence were examined: stress and accent. To separate stress from accent, four frame sentences elicited the test words in accented positions bearing the nuclear pitch accent, and three in de-accented positions following the nuclear pitch accent by several words. Accented test words were not contrastively focused. To assess the effect of prosodic boundaries, the test words were phrase-final (IP boundary) in seven of the frame sentences and phrase-medial (W boundary) in two. To match the comparisons on accentual status in phrase-final positions, one W frame sentence elicited the test words in accented phrase-medial position, and the other W frame sentence in de-accented phrase-medial position. In total, 243 test utterances were used (3 test words x 9 sentences x 9 repetitions). All test sentences involved the same number of syllables, and the same words immediately before (/ˈɛkɔpi/, 'raw') and immediately after (/metɛ'ksi/, 'among') the test word. Seven of the frame sentences needed contextualizing sentences in order for the appropriate intonational contour to be elicited. An

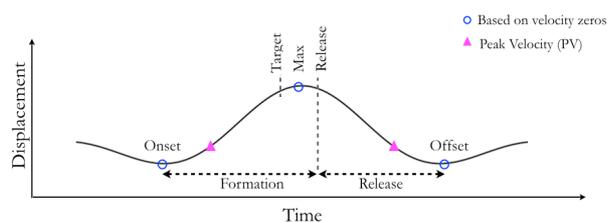
example stimulus is shown in (1) (see [15, 16] for the entire list of stimuli):

- (1) [ɛnɛzi'tɛs 'ɛkɔpi 'mēmimē # metɛ'ksi mɛθi'tɔn  
ɛ'vrɛɔs ðjɛci'nitɛ]#  
*Are you looking for raw MAmima? Usually one  
can find some among students.*

### 2.3. Annotation and analysis

The data were first subjected to the TAPADM pre-processing procedure [14] and to prosodic analysis using GrToBI [2]. Utterances produced with disfluencies or alternative, not the targeted, intonational contours were disregarded, resulting in 5-15 tokens per test word in each sentence per speaker. Next, the formation phase of the test constrictions were semi-automatically labeled, employing custom software (Mark Tiede, Haskins Laboratories), for the following kinematic timepoints (see Figure 1): onset, peak velocity, target, constriction maximum and release. Consonant (C) gestures were also annotated for peak velocity and offset of the gesture's release. These timepoints were not detected for the vowel (V) gestures, because the release of a V gesture coincides with the formation of the next one. C gestures (all labial) were labeled on the lip aperture tract, and V gestures on the tongue dorsum vertical displacement tract. Based on these timepoints the following measures were calculated: 1) formation duration: the interval between onset and release, and 2) release duration (only for C constrictions): the interval between release and offset (see Figure 1).

**Figure 1:** The timepoints of constriction gestures.



The scope of prominence was evaluated across the whole test word (i.e., the C and V gestures of the first, second and third syllable of the test words, referred to as C1, C2, C3, V1, V2, and V3 respectively) and the first post-boundary consonant (referred to as C4). Repeated measures ANOVAs were performed on the duration of each gesture of this stretch using R [19]. Stress position (levels: S1, S2 and S3), accentual status (levels: accented, de-accented) and boundary type (levels: IP, W) were the fixed factors, and speaker the repeated factor. Significant effects ( $\alpha = 0.05$ ) were followed by pairwise comparisons ( $\alpha = 0.05$ ) using the Bonferroni adjustment in cases of multiple comparisons.

### 3. RESULTS

As Table 1 shows, stress position had a significant main effect for all test gestures, except for the release of the post-boundary C4. Interaction effects between stress position and boundary type were found for C1 formation ( $F(2,8) = 7.025, p < 0.05$ ), V2 formation ( $F(2,8) = 9.428, p < 0.05$ ), C3 formation ( $F(2,8) = 14.11, p < 0.05$ ), C3 release ( $F(2,8) = 12.38, p < 0.05$ ), and C4 formation ( $F(2,8) = 6.282, p < 0.05$ ). Accentual status did not systematically interact with stress position. Two interaction effects of this type were observed, one on C2 formation ( $F(2,8) = 8.64, p < 0.05$ ) and one on V2 formation ( $F(2,8) = 4.491, p < 0.05$ ). Finally, an interaction effect among stress position, accentual status and boundary type was detected on V3 formation ( $F(2,8) = 5.749, p < 0.05$ ). In what follows, the post-hoc comparisons for the main effect of stress position and its interactions with boundary type are reported. The other interactions were not systematic and did not affect the scope of lengthening, and are thus not discussed further.

**Table 1:** The main effects of Distance of Stress detected by the Repeated Measures ANOVAs. F stands for formation and R for release.

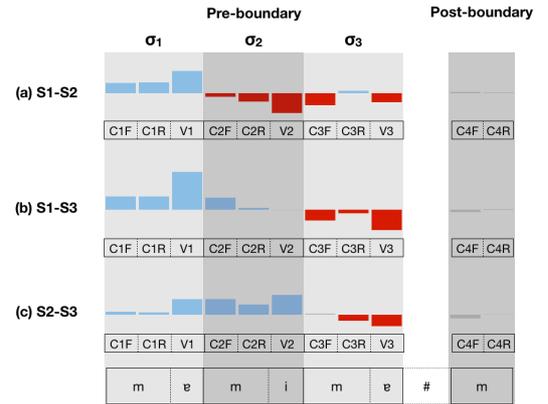
C1 F	$F(2,8) = 14.29, p < 0.05$
C1 R	$F(2,8) = 16.95, p < 0.05$
V1 F	$F(2,8) = 34.84, p < 0.05$
C2 F	$F(2,8) = 42.82, p < 0.05$
C2 R	$F(2,8) = 7.72, p < 0.05$
V2 F	$F(2,8) = 27.7, p < 0.05$
C3 F	$F(2,8) = 18.38, p < 0.05$
C3 R	$F(2,8) = 12.4, p < 0.05$
V3 F	$F(2,8) = 26.41, p < 0.05$
C4 F	$F(2,8) = 15.63, p < 0.05$

Figure 2 schematically represents the distribution of prominence-induced lengthening based on the post-hoc pairwise comparisons, illustrating how the scope of the effect varies with stress position. The post-hoc pairwise comparisons (see Table 2 for mean durations) showed that when a syllable is stressed, its gestures are longer than when the same syllable is unstressed ( $p < 0.05$  for all comparisons). The only exception is C3 formation, which is not longer when the stress is on its syllable (S3) as opposed to one syllable earlier (S2) ( $p < 0.05$ ), presumably due to spill-over effects of penultimate (S2) stress.

What is of special interest here is the finer distinctions detected between unstressed syllables. Gestures of the first and final syllable were longer when the stress was on the immediately adjacent syllable than on the syllable two syllables away ( $p < 0.05$  for all comparisons), indicating that stress

effects extend both after (see Figure 2a) and before (see Figure 2c) the stressed syllable respectively. An interesting exception is C3 release, which is slightly longer when stress is the furthest away possible as opposed to neighbouring (S1 > S2,  $p < 0.05$ ) (see Figure 2a). As for C2, both its formation and its release were longer when stress was antepenultimate as opposed to ultimate (S1 > S3,  $p < 0.05$ ), providing evidence for spill-over effects being stronger than anticipatory effects (see Figure 2b). No significant comparisons of stress position were found for unstressed V2 and C4 formations.

**Figure 2:** Schematic representation of the durational difference between the members of stress position comparisons for each gesture. Light blue (positive) boxes indicate significant longer durations for the first member of the comparison (e.g., S1 in S1-S2), and dark red (negative) boxes indicate significant longer durations for the second member (e.g., S2 in S1-S2). F stands for formation, R for release, and  $\sigma$  for syllable.



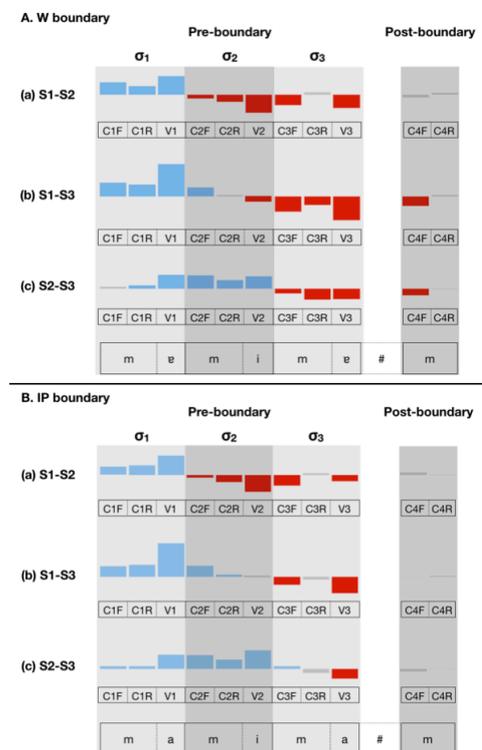
**Table 2:** The mean duration (in ms) followed by standard deviation within parentheses for each test constriction gesture per stress condition. F stands for formation and R for release.

	S1	S2	S3
C1 F	101.59 (18.90)	85.41 (22.04)	80.16 (21.31)
C1 R	65.88 (14.26)	48.37 (10.54)	43.52 (7.93)
V1 F	172.38 (28.44)	135.37 (23.60)	109.27 (17.42)
C2 F	85.12 (12.77)	90.54 (17.59)	64.65 (14.01)
C2 R	44.81 (13.95)	58.72 (12.58)	41.75 (16.28)
V2 F	148.18 (22.14)	180.62 (33.70)	148.11 (19.98)
C3 F	75.36 (16.77)	95.02 (15.95)	92.91 (20.15)
C3 R	80.62 (22.59)	76.82 (20.76)	86.51 (18.23)
V3 F	153.86 (32.55)	169.35 (34.10)	188.09 (31.92)
C4 F	102.97 (54.15)	100.97 (40.74)	107.04 (41.05)
C4 R	90.29 (31.04)	88.91 (30.09)	88.87 (28.85)

The analysis on the interaction of stress position with boundary type was also revealing, showing that lengthening crosses word boundaries, regardless of source of prominence. As Figure 3 illustrates, in the word (W) boundary condition, the first post-boundary C gesture (C4) has a longer formation phase when the stress of the preceding word is

ultimate (S3; mean 86.31 ms, SD: 25.33 ms) as opposed to either antepenultimate (S1; mean: 67.72 ms, SD: 21.16 ms) or penultimate (S2; mean: 73.39 ms; SD: 27.95 ms) ( $p < 0.05$  for both comparisons). The effect does not hold if C4 follows an IP boundary.

**Figure 3:** Schematic representation of the durational difference between the members of stress position comparisons for each gesture in W and IP boundary respectively. Light blue (positive) boxes indicate longer durations for the first member of the comparison, and dark red (negative) boxes longer durations for the second member. F stands for formation, R for release, and  $\sigma$  for syllable.



Additional interactions between stress position and boundary type were observed pre-boundary. C1 formation is longer in S2 (mean: 85.45 ms, SD: 21.08 ms) as compared to S3 (mean: 79.56 ms, SD: 21.33 ms) phrase-finally (IP) ( $p < 0.05$ ), but not phrase-medially (W). V2 formation is longer in S3 (mean: 149.78 ms, SD: 17.99 ms) as compared to S1 (mean: 139.36 ms, SD: 22.32 ms) when the word is phrase-medial (W) ( $p < 0.05$ ). Phrase-finally, this effect disappears. Finally, in C3 formation, lengthening presents different direction between the two boundary types. In W, C3 formation is longer when stress is ultimate (S3; mean: 93.64 ms, SD: 19.67 ms) as compared to penultimate (S2; mean: 84.54 ms, SD: 13.48 ms) ( $p < 0.05$ ), whereas in IP, the opposite is true (S2 > S3,  $p < 0.05$ ; S2 mean: 98.02 ms, S2 SD: 15.34 ms; S3 mean: 92.67 ms, S3 SD: 20.33 ms).

## 4. DISCUSSION

Our findings indicate that the scope of prominence-induced lengthening extends over a continuous stretch of speech (see Figures 2 and 3). This contrasts with [10], which found that contrastive accent in Standard Scottish English affected not a continuous stretch of speech, but instead, multiple domains, including the stressed syllable, the rhyme of the following syllable, the word-final syllable, and the word-initial segment. This contrast could be due to a cross-linguistic difference: Greek and Standard Scottish English might employ different mechanisms for marking prominence. Alternatively, this contrast might reflect two different levels in the hierarchy of prominence, with contrastive accent being a higher level than non-contrastive accent (cf. [18]). If this is the case, contrastive accent is related to longer durations [18] and affects a larger stretch of speech to highlight the prominent syllable but also demarcate the edges of the prominent word, as proposed in [10]. Note though that lengthening here crosses word boundaries when the stress is ultimate (see also [22, 23]).

In addition, our results indicate that in Greek, stress and non-contrastive accent do not affect the scope of lengthening differently. In parallel, the magnitude of lengthening in Greek has been found to be similar between stress and non-contrastive accent [17]. These findings are taken to suggest that in Greek, like in Arabic [9], prominence-induced lengthening is not cumulative (i.e., increasing with higher degrees of prominence). Instead, lexical stress modulates the supra-laryngeal, kinematic duration of gestures, while non-contrastive accent is marked by a pitch accent on the stressed syllable [2]. Based on the conclusions of the last two paragraphs, it remains to be seen whether magnitude and scope of prominence-induced lengthening are further controlled by focus structure, by examining all focus types, including contrastive focus (cf. [18]).

Although the exact scope of the prominence-induced lengthening varies with stress position, it can be concluded that it begins before and ends after the stressed syllable. The terms *anticipatory* and *spill-over* have been used to capture lengthening before and after the stressed syllable respectively, implying that these are automatic reflexes of the production of stress on the stressed syllable. However, it is unclear whether these effects are indeed automatic reflexes or planned. Certainly, lengthening is the strongest on the V gesture of the stressed syllable and decreasing with distance from it, as illustrated in Figures 2 and 3, and spill-over effects are stronger than anticipatory effects, supporting the automatic reflexes account.

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