



Preboundary Lengthening in Modern Standard Arabic: Effects of Syllable and Word Boundaries

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Abstract

This study examines preboundary lengthening in Modern Standard Arabic, focusing on the role of syllable structure and word boundaries within the prosodic hierarchy. Acoustic data were obtained from two female Lebanese broadcasters, targeting the vowel /a/ preceding nasal consonants (/n/, /m/) across three prosodic contexts: syllable-medial (/CVN/), syllable-final (/CV.N/), and word-final (/CV#N/). A total of 876 tokens were analysed using linear mixed-effects models. The results reveal significant preboundary lengthening exclusively in word-final position, while no statistically significant lengthening was observed in syllable-final or medial contexts. These findings indicate that the word, rather than the syllable or rime, constitutes the primary domain anchoring preboundary lengthening in Modern Standard Arabic. The results further suggest that prosodic boundary strength does not uniformly scale across lower-level domains, highlighting language-specific modulation of temporal patterns. This study contributes to ongoing cross-linguistic debates on prosodic structure and provides empirical evidence for the phonetics–phonology interface in Arabic.

Key words: *Preboundary lengthening; prosodic hierarchy; Modern Standard Arabic; phonetics–phonology interface.*

1. Introduction

In connected speech, individual speech sounds ‘segments’ are grouped into larger units, often known as prosodic domains such as syllables, words, phrases and intonation phrases etc. This neatly organised prosodic structure is known as the prosodic hierarchy (Shattuck-Hufnagel & Turk 1996). Because the organisation of utterances cannot be fully predicted by syntactic structure, the prosodic hierarchy has been postulated as an alternative organisational structure having its own component of the grammar (Beckman, 1996). There is evidence that prosodic structure affects the phonetic shape of individual speech segments in many ways (Wightman et al., 1992; Cho 2004; Cho, 2016). One way of such effects can be seen in final “preboundary lengthening”, referring to the spatial and/or temporal expansion of phonological units (e.g., vowels, consonants, syllables etc.) at the right edge “end” of prosodic domains (Edwards, Beckman & Fletcher, 1991; Wightman et al., 1992; Turk & Shattuck-Hufnagel, 2007; Cho, 2016). Cross-linguistic studies have shown that vowel duration becomes longer at the end of higher prosodic domains (Cho, 2004; Maiteq, 2013), a phenomenon often known as preboundary lengthening. Preboundary lengthening gradually increases, with vowels at the right edge of higher ‘stronger’ domains being longer than those at the end of lower ‘weaker’ domains (Cho, 2004; Maiteq, 2013), Cho, 2015 for a discussion). Thus, preboundary lengthening is a phonetic cue that speakers employ to signal prosodic structure levels. This signalling aids listeners, therefore, to expect the upcoming stream of speech.

The aim of the present study is to examine how preboundary lengthening can be affected by syllable structure and word boundaries in Modern Standard Arabic.

1. 1 Literature review

Vowel lengthening can be determined by a number of factors including inherent segmental properties, voicing of the following consonant (e.g., Keating, 1984). Relevant to the present study, early studies of English vowel duration established that *syllable structure* systematically influences vowel duration. For example, vowels are longer in open syllables than in closed syllables, a cross-linguistic tendency known as closed syllable shortening (Maddieson, 1984). Supporting evidence comes from Korean, where Han (1964, cited in Maddieson, 1984: 93) found that the mean duration of the vowel /a/ in CV syllables was 266 ms, compared to 127 ms in CVC syllables. While other studies report acoustic vowel duration differences between open and closed syllables (e.g., Maddieson, 1985;), Kim, Kim & Cho (2024) reported data from Korean showing that these differences are grounded in articulatory kinematics. Vowels in open syllables (CVCV#) show greater displacement and longer gestural timing than those in closed syllables (CVCVC#). This difference is attributed to articulatory kinematics, where open syllables allow for more expanded and slower articulatory gestures.

Data from Japanese show that V₂ in open syllables (CV₁C V₂) lengthens to about 40 ms at the end of intonation phrase, whereas in closed syllables (CV₁CV₂C) the duration of V₂ is about 20 ms. This shows that syllable structure significantly constrains the magnitude of preboundary lengthening (Seo,

Kim & Cho, 2019). This variation in vowel duration can be interpreted in terms of boundary effect. In the vicinity of syllable boundary /CV/ a vowel becomes longer than when it is separated by segment(s) from the syllable boundary. As noted by an anonymous reviewer, some Arabic dialects (e.g., Egyptian Arabic) do not allow superheavy syllables in non-final positions (e.g., /beet/ ‘home’ → /bet.na/ ‘our home’; ?ari:b → ?arib.kum ‘your m. pl. relative’).

While these findings show how vowel duration can be shaped by syllable structure, other research shows that prosodic structure significantly influences individual segments at higher levels of the hierarchy, with phonetic signalling extending beyond the segmental level.

A relevant theoretical issue is whether preboundary lengthening progressively increases in a way that mirrors the hierarchical organisation of prosodic domains. Research on prosodic structure has demonstrated that preboundary lengthening is used by speakers as a phonetic cue to signal higher level prosodic domains of varying strengths. Acoustic and articulatory (EMA) data in Cho (2004) demonstrated that when English vowels /a/ and /i/ occur domain-finally, their duration increases progressively with prosodic boundary level, i.e., strength. More clearly, Cho’s data showed that vowels are shortest within prosodic words, longer at phrase boundaries, and maximally lengthened at the end of intonation phrase. This hierarchical increase in preboundary segments shows that prosodic structure directly conditions preboundary lengthening. Supporting evidence from English showed that word-final vowels are shorter in the

middle of a phrase than at the end of a phrase, and word-final vowels at the end of a phrase are shorter than when they are at the end of an intonation phrase (Wightman et al 1992). Data from Jordanian Arabic (de Jong and Zawaydeh, 1999) showed that vowel durations are robustly influenced by higher level prosodic structure. For example, vowels are longer in utterance-final positions than in non-utterance final positions. In addition, at the level of intonation phrase, vowels in penultimate syllables are longer than in antepenultimate syllables. Acoustic data from Libyan Arabic showed that the durations of Libyan Arabic vowels /a/ and /i/ progressively increase at the end of word, phrase and intonation phrase (Maiteq, 2013). Beckman & Edwards (1990) reported that in English an entire syllable at the end of a phrase is considerably longer than when it is at the end of a word. Jun (1993) reported data from Korean, reinforcing the view that preboundary lengthening progressively increases across multiple levels of the prosodic hierarchy.

Another theoretical issue aligned within discussions of preboundary lengthening is the *domain* of lengthening. Wightman et al. (1992) examined whether segmental lengthening in English extends beyond the immediate boundary. They found that the effect is localised to the rime of the syllable preceding the boundary, showing the syllable rime as the domain. Turk & Shattuck-Hufnagel (2007) reported data showing the rime as a domain for preboundary lengthening in English.

Subsequent work has shown that the operative domain varies cross-linguistically. Earlier studies have demonstrated that the mora is a key timing unit in Japanese (Kubozono, 1989;

1993). It is thus possible to hypothesise that preboundary lengthening is tied to the mora rather than to the syllable structure (see Seo et al., 2019, for discussion). However, recent experimental research has shown that although preboundary lengthening is independent of mora count and more structure, it is attracted toward a non-final moraic nasal, showing some role of the mora (Seo et al., 2019). Thus, these cross-linguistic variations indicate that the domain of preboundary lengthening is not universal but rather varies according to the prosodic structure of individual languages, and is therefore controlled by the speaker. Shubo & Zerbian (2023) examined penultimate and antepenultimate word stress with the absence/presence of an additional word-final consonant (CV.CV.CV vs CV.CV.CVC) in German. Their results showed that the domain of preboundary lengthening is the nuclear vowel of the main stress. Further evidence for preboundary lengthening domain was reported for consonants in modern Hebrew (Berkovits, 1993). Results in Berkovits (1993) revealed that utterance-final fricatives underwent more lengthening than the stressed vowel preceding them. Thus, examining Arabic allows us to ask whether the syllable, the rime, the word, or another unit serves as the operative domain for preboundary lengthening.

These studies have consistently demonstrated that vowels lengthen in domain-final positions, suggesting that preboundary lengthening is a robust phonetic correlate of prosodic domains and phrasing (e.g., Pierrehumbert & Talkin 1992; Maiteq, 2013). Importantly, these studies have also shown that vowel lengthening might be

influenced by syllable structure: closed syllables tend to shorten vowel duration relative to open syllables. Taken together, these findings underscore the need to examine how preboundary lengthening interacts with syllable structure and word boundary junctures in Modern Standard Arabic.

By investigating vowel lengthening across varying prosodic levels—within syllables and across syllable and word boundaries—the present study aims to uncover information regarding prosodically-driven phonetic realisations of speech sounds. Such an approach not only refines our understanding of temporal variation in Arabic but also contributes to broader debates on the phonetics-phonology interface. On the basis of this review, the following predictions are proposed.

1. 2 Predictions

If Arabic implements a progressively increasing preboundary lengthening, then the shortest duration, based on the closed syllable vowel shortening hypothesis, is predicted for syllable-medial positions (/CVN/), where no boundary intervenes. Word-final positions (/CV#/) are expected to show the longest duration, reflecting the greatest preboundary lengthening. Syllable-final positions (/CV./) are predicted to occupy an intermediate position, exhibiting moderate lengthening relative to medial but less than word-final vowels, based on the hypothesis that syllable boundary is the weakest boundary in the present data.

2. Methodology

2.1. Participants, data and measurements

Data from Modern Standard Arabic was obtained from two female Lebanese broadcasters (one from Aljazeera, one from Al-Araby) news channels. Two files (one for each speaker) were downloaded from

YouTube and converted into WAV files. All tokens were selected as having the phonetic sequence /CVN/, where N was /n/ or /m/. The selected tokens were intended to render a hierarchy of prosodic boundary strength: zero-boundary in closed syllable (CVN), syllable boundary in open syllable (CV.N), and word boundary with open syllable at the end of the word (CV#N).

Table 1. Target sequences embedded in three prosodic locations.

Position	Structure	Word	Gloss
Syllable-Medial	/CVC/	ʔajdʕan	‘also’
Syllable-Final	/CV./	bana	‘(he) built
Word-Final	/CV#./	ðahaba # naha:ran	‘(he) went during the day’

Acoustic measurements of vowel duration were carried out using Praat software for speech analysis (Boersma & Weenink, 2026), with the following settings: for (spectrogram) analysis window length 5 ms, dynamic range 70 db; (for formant) maximum formant 5500-6000 Hz suitable for all adult female speakers, number of formants 5, analysis window length

25 ms, dynamic range 40 db, and pre-emphasis $f_p = 2.23e-08$ from 50 Hz, using the Burg algorithm. Segmentation of the data was based on defining constriction onsets and releases as outlined in Turk et al (2006), see Figure 1.

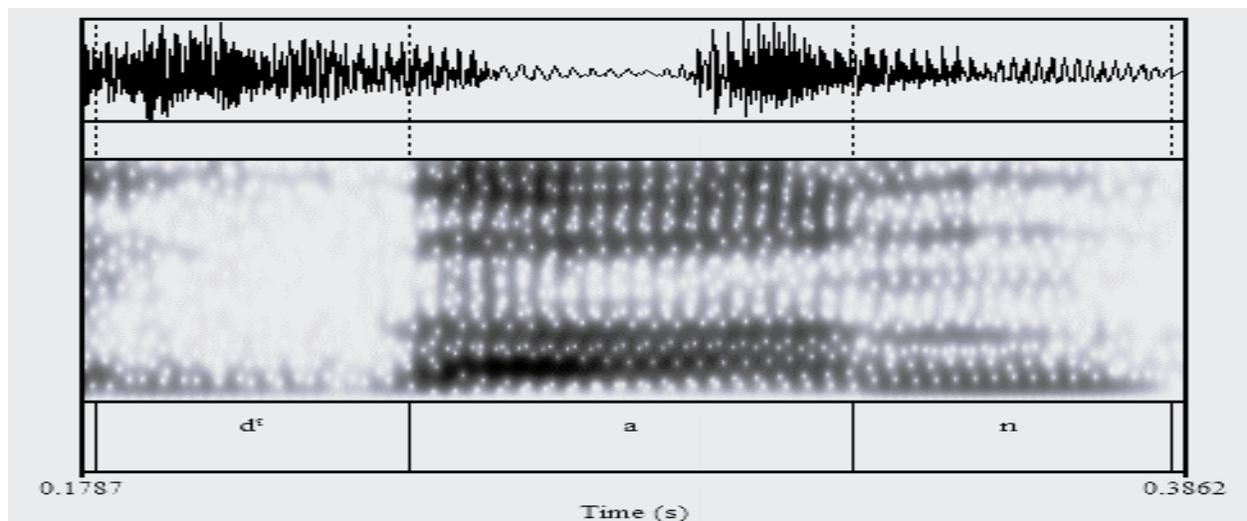


Fig. 1. A portion from the word /ʔajdʕan/ ‘also’ representing /CVC/ condition.

2.2. Data Analysis

A total number of 876 tokens was submitted to linear mixed effects (LME) analysis with the R open-source language and environment for statistical computing (R Development Core Team, 2025). A variety of LME models were constructed using the *Lme4* package (Bates et al. 2015). Data plotting was carried out using the *ggplot2* package (Wickham 2016). By-hand computations of coefficient adjustments were carried out as recommended in (Winter, 2020). Model comparison was carried out by a likelihood ratio test using the *anova()* R function. The best-fit that converged was constructed with vowel duration as the dependent variable, prosodic position as a fixed predictor (with the Syllable-medial condition as a reference level). Random intercepts for Speaker and Word were included in the random structure of the model.

3. Results

Results of Linear mixed effects analysis are summarised in Figure 2 and table 2. By-hand coefficient computation is presented in table 3, as outlined in (Winter, 2020). Results show

that the intercept, referring to the vowel duration in syllable-medial position /CVC/ is (82.0 ms, $p = 0.05$). The coefficient representing vowel duration in syllable-final position /CV.N/ does not show a significant increase as compared to the intercept ($82.0 + 0.6 = 82.6$ ms, $p = ns$). In contrast, vowel duration in word-final position /CV#/ significantly increased by 16.6 ms ($82.0 + 16.6 = 98.6$, $p = 0.001$). As shown in Figure 2, predicted duration values of vowels preceding a word boundary /CV#/ are robustly longer than syllable-medial and syllable-final vowels. However, predicted values of vowel durations are not significantly different.

Random intercepts were included for Word and Speaker. The variance associated with Word 900.25 (SD = 30.0) was considerably larger than that for Speaker 31.76 (SD = 5.6). These suggest that differences across test words contributed more to variability in vowel duration than differences across speakers. The residual variance 234.96 (SD = 15.3) reflects within-word and within-speaker variation across tokens.

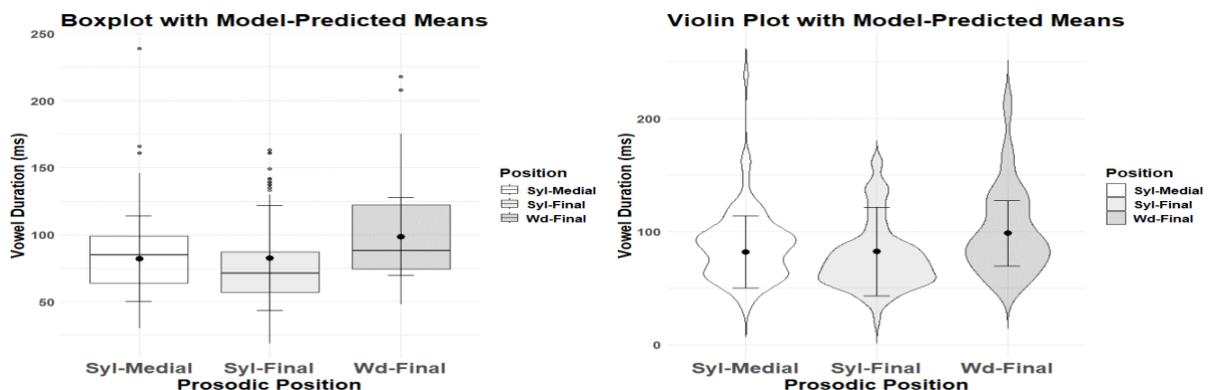


Fig. 2. Boxplot and violin plot showing model predicted vowel duration (ms) across prosodic position

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Table 2. Results for the Linear mixed effects model with the formula: Vowel Duration ~ Position + (1 | Speaker) + (1 | Word).

Random Effects					
Group	Name	Variance	Std. Dev.		
Word	(intercept)	900.25	30.004		
Speaker	(intercept)	31.76	5.636		
Residual		234	15.328		
Number of Obs.	876		Groups: Word, 197; Speaker, 2		
Fixed Effects					
	Estimate	Std.Error	df	T value	P-value
(Intercept)	82.0067	4.8315	1.3951	16.973	0.0138
Position Syl-Final	0.6619	2.3364	861.8396	0.283	0.7770
Position Wd-Final	16.6490	2.9490	864.7594	5.64	2.23e-08

Table 3. By-hand computation of vowel durations as predicted in the model.

Prosodic Position	Coefficient Computation	Predicted Duration (ms)
Syllable-medial [CVN]	82.0067	82.01 (p = 0.05)
Syllable-final [CV. N]	82.0067 + 0.6619	82.67 ns.
Word-final [CV#N]	82.0067 + 16.6490	98.66 (p = 0.001)

These findings suggest that preboundary lengthening is tied to word boundary prosodic strengthening, consistent with prior accounts of boundary-driven temporal adjustment. These findings suggest that the domain of preboundary lengthening in Modern Standard Arabic is the word. An anonymous reviewer has pointed out that morpheme boundaries may be relevant, particularly in light of the phonologically derived environment effect. While our study is phonetic in nature and focuses on syllable and word boundaries, prior work has shown that morpheme boundaries can condition prosodic and phonetic realisation (e.g., Cho 2001). Future research should examine whether such effects extend to

preboundary lengthening in Modern Standard Arabic.

4. Discussion

The present findings suggest a significant effect of word boundary on preboundary lengthening. The duration of word-final vowels increased by 16 ms, as compared to syllable-medial vowels (p = .001). By contrast, syllable-final vowels did not differ significantly from syllable-medial counterparts. These findings confirm predictions of cumulative preboundary lengthening at higher prosodic levels, while providing no evidence for syllable-level lengthening. Thus, the present findings suggest that the domain of preboundary lengthening in Modern Standard Arabic is the word rather than the syllable.

These findings have a direct bearing on two theoretical issues raised in the literature review. First, they do not seem to support the closed syllable vowel shortening hypothesis. There was no significant vowel duration increase in the vicinity of syllable boundary. In a similar vein, Maiteq (2013) found that

pharyngealisation magnitude is categorical inside the word (across syllable boundaries) and gradient across word boundaries. Taken together with the present findings, one possible interpretation is that word-internal boundaries seem too weak to trigger strengthening effects such as preboundary lengthening.

Second, the present findings identify the word as the domain of preboundary lengthening in Modern Standard Arabic. Previous research has proposed different units serving as preboundary domains: the final syllable, rime, or word in English (Wightman et al., 1992; Turk & Shattuck-Hufnagel, 2007), the nuclear vowel of the main stress in German (Shubo & Zerbian; 2023), the mora in Japanese (Kubozono, 1989; 1993), and disyllabic words in Modern Hebrew (Berkovits, 1993). Our results diverge from the English and Japanese patterns, instead pointing to the word as the domain. In this respect, Arabic aligns with Hebrew in exhibiting robust lengthening at the word boundary.

Based on the present data, preboundary lengthening in Modern Standard Arabic appears to be prosodically-modulated, consistent with the view that prosodic domains are hierarchically organized. Ultimately, the evidence suggests that while preboundary lengthening may reflect a universal tendency to cue prosodic boundaries, its phonetic implementation is controlled by the speaker in a language-specific way, with Modern Standard Arabic privileging the word domain of preboundary lengthening. A limitation of the

present study is that the data derive from Lebanese broadcasters producing Modern Standard Arabic. As such, the observed preboundary lengthening reflects Lebanese-accented realisations of Modern Standard Arabic rather than an abstract “native” Modern Standard Arabic system. This limitation is inherent to the study of Modern Standard Arabic, since the variety has no native speakers and must always be examined through the productions of speakers with dialectal backgrounds. Broadcasters, however, are widely recognised as trained exemplars of Modern Standard Arabic performance, and their speech constitutes the socially accepted form of Modern Standard Arabic in public communication. Our findings therefore highlight how prosodic boundary effects are implemented in Modern Standard Arabic as performed by Lebanese speakers, while underscoring the broader methodological reality that empirical investigations of Modern Standard Arabic phonetics can only be conducted through such dialectally grounded realisations.

5. Conclusion and Recommendations

The findings suggest a robust preboundary lengthening in the vicinity of word boundaries in Modern Standard Arabic. Preboundary lengthening takes the word as a domain rather than the syllable, highlighting a language-specific prosodic organisation. Taken together, these findings show that prosodic hierarchy is phonetically cued in Modern Standard Arabic, providing crucial evidence for ongoing debates on the phonetics-phonology interface. These results are preliminary, and further research on

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Arabic is needed to include other vowels and consonants, more speakers, higher prosodic boundary types and other prosodic factors such as stress and prominence.

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Conflict of Interest:

The authors declare no conflict of interest.

Declaration of AI Use

The authors acknowledge the use of AI tools (e.g., Copilot) exclusively for R coding. No AI tools were used for data analysis, interpretation, or content generation.

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إطالة ما قبل الحد في العربية الفصحى الحديثة: آثار حدود المقطع والكلمة

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ملخص البحث:

تهدف هذه الدراسة إلى فحص ظاهرة الإطالة قبل الحدّ (preboundary lengthening) في العربية الفصحى المعاصرة، مع التركيز على دور بنية المقطع وحوادث الكلمة ضمن التسلسل الهرمي النبري. تم جمع بيانات صوتية من مديعتين لبنانيتين، مع التركيز على الصائت /a/ قبل الصوامت الأنفية (/m, n/) في ثلاثة سياقات عرضية: داخل المقطع (/CVN/)، نهاية المقطع (/CV.N/)، ونهاية الكلمة (/CV#N/). شملت العينة 876 حالة خضعت لتحليل النماذج الخطية المختلطة. أظهرت النتائج وجود إطالة دالة إحصائياً في موقع نهاية الكلمة فقط، في حين لم تظهر فروق دالة في موقعي نهاية المقطع أو داخله. تشير هذه النتائج إلى أن الكلمة تمثل المجال الأساسي للإطالة قبل الحدّ في العربية الفصحى، وليس المقطع أو القافية. كما تدعم النتائج فكرة أن هذه الظاهرة تخضع لضبط عرضي خاص باللغة، مما يثري النقاشات عبر اللغوية حول البنية العرضية وواجهة الصوتيات-الفونولوجيا.

الكلمات المفتاحية: الإطالة قبل الحدود؛ التسلسل التطوري؛ العربية الفصحى الحديثة؛ واجهة الصوتيات؛ علم الأصوات.