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الإطالة قبل الحدود في اللغة العربية الفصحى الحديثة: تفاعل حدود المقطع والكلمة

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الملخص:

تتناول هذه الدراسة الصوتية ظاهرة الإطالة قبل الحدود في العربية الفصحى الحديثة، مع التركيز على مدة الحركة العالية /i/ داخل حدود المقطع، وعبر حدود المقطع والكلمة: في الموقع الوسطي(/CVN/) ، وفي نهاية المقطع(/CV.N/) ، وفي نهاية الكلمة .(/CV#N/) أظهرت النتائج زيادة تدريجية في مدة الحركة تبعاً لقوة الحد، مما يرسخ تمييزاً ثلاثياً في مدة الحركة: الأقصر في الموقع الوسطي، والأطول عبر حدود المقاطع، والأطول على الإطلاق عبر حدود الكلمات. وعلى خلاف النتائج السابقة الخاصة بالحركة المنخفضة/a/ ، التي أظهرت إطالة فقط عند حدود الكلمات، فقد أظهرت الحركة العالية /i/ زيادة تدريجية في المدة عبر كل من حدود المقاطع والكلمات. وتشير هذه النتائج إلى أن الإطالة قبل الحدود تتشكل وفق البنية النبرية. كما أن المقارنة عبر اللغات تضع العربية ضمن نطاق المقطع في ظاهرة الإطالة قبل الحدود، في مقابل الرّم في الإنجليزية والمورا في اليابانية، لكنها تتوافق مع لغات مثل العبرية الحديثة. وتناقش هذه النتائج في إطار التنفيذ الصوتي الخاص بكل لغة الذي يحدد صياغة العبارات النبرية، مما يسهم في النقاشات المستمرة عند تقاطع الصوتيات والنبر.

الكلمات المفتاحية :الإطالة قبل الحدود، قوة الحدود النبرية، بنية المقطع، مدة الحركة، حدود الكلمة.

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

A B S T R A C T:

The present acoustic study examined preboundary lengthening in Modern Standard Arabic, focusing on the duration of the high vowel /i/ within syllable boundaries, and across syllable and word boundaries: syllable-medial (/CVN/), syllable-final (/CV.N/), and word-final (/CV#N/) positions. Results revealed a gradient increase in vowel duration with boundary strength, establishing a three-way vowel duration distinction: shortest in medial position, longer across syllable boundaries, and longest across word boundaries. Unlike prior findings for the low vowel /a/, which showed lengthening only at word boundaries, the high vowel /i/ exhibited progressively increasing duration across both syllable and word boundaries. These results suggest that preboundary lengthening is shaped by prosodic structure. Cross-linguistic comparison situates Arabic within a syllable domain for preboundary lengthening, contrasting with the rime in English and the mora in Japanese but aligning with languages such as Modern Hebrew. These results are discussed in terms of language-specific phonetic implementation that demarcates prosodic phrasing, contributing to ongoing debates at the phonetics-prosody interface.

Keywords: Preboundary lengthening, Prosodic boundary strength, Syllable structure, Vowel duration, Word boundary.

Introduction

Prosodic structure organises speech into a hierarchy of boundaries, from the syllable to the word and beyond, and these boundaries systematically shape temporal patterns such as vowel duration. Syllable structure exerts a subtle yet systematic influence on vowel duration, revealing cross-linguistic tendencies at the phonetics–prosody interface. Vowels are typically longer in

syllable-final position /CV.N/ than in syllable-medial position /CVN/, underscoring how syllable boundaries modulate temporal adjustments in speech. Beyond the syllable, vowel duration also increases near stronger prosodic boundaries: vowels preceding word boundary are longer than those preceding relatively weaker boundaries such as the syllable. Situating these positional effects within a broader prosodic framework—where prosodic phrasing and boundary strength converge—shows how low-level phonetic implementation is shaped by high-level prosodic structure. The present study investigates preboundary vowel lengthening in Modern Standard Arabic, focusing on syllable and word boundaries.

Statement of the problem

Prosodically-induced vowel lengthening has been widely studied across languages, where it may anchor in different domain units However, its domain in Modern Standard Arabic remains underexplored and inconsistently reported, with prior findings limited to the low vowel /a/ and word-final contexts. This gap raises the problem of whether Arabic exhibits systematic preboundary lengthening across different boundary strengths, and how it aligns with cross-linguistic patterns. Addressing this problem is essential for clarifying the prosodic domain of Arabic and for contributing to broader debates at the phonetics-prosody interface.

Research aims and objectives

The study aims to investigate how prosodic boundary strength influences vowel duration in Modern Standard Arabic, with a focus on preboundary lengthening. Thus the aim is to examine vowel duration across three structural positions: syllable-medial (/CVN/), syllable-final (/CV.N/), and word-final (/CV#N/). More specifically, we aim to compare the behaviour of vowel duration in relation to boundary strength. It is also important to situate Arabic within cross-linguistic patterns of preboundary lengthening, contrasting its magnitude and domain with other languages (e.g., English, Japanese, Modern Hebrew).

Research Questions

1. How does prosodic boundary strength affect vowel duration in Modern Standard Arabic? Does vowel duration differ systematically in syllable-medial (/CVN/), syllable-final (/CV.N/), and word-final (/CV#N/) positions?
2. Is preboundary lengthening categorical or gradient?
3. What is the domain of vowel duration?

To motivate the present investigation, previous literature is reviewed in three distinct areas: 1) vowel duration variations due to inherent segmental properties, 2) effects of presence/absence of syllable boundaries, and 3) the role of prosodic boundary strength by including the word boundary effect. Previously proposed magnitudes and domains of vowel duration are also reviewed.

Literature review

Studies of vowel duration provide evidence for a segmental level of organisation. Cross-linguistically, the low vowel /a/ is inherently longer than the high vowel /i/ (Keating, 1984; Lehiste, 1970), indicating to a universal phonetic tendency. A physical explanation has been suggested in (Lehiste, 1970) where a lower vowel is inherently having a greater articulatory movement. Lehiste notes that if vowels have approximately similar movement velocity, then it is plausible to assume that lower vowels are longer than high vowels.

Recent research on Modern Standard Arabic has shown that preboundary lengthening of the low vowel /a/ is tied to the word boundary level, rendering syllable boundaries invisible to this process (Maiteq, in press). The present study therefore extends the investigation to the high vowel /i/ to assess whether segmental variation emerges.

Cross-linguistic evidence shows that syllable structure plays a significant role in vowel duration: vowels are generally longer in open syllables than in closed syllables, a cross-linguistic tendency known as closed syllable shortening (Keating, 1979; Maddieson, 1984; Kubozono, 2017). In English, vowels are longer in open syllables than in closed ones (Abercrombie, 1967; Maddieson, 1984). Maddieson (1984) reports mean durations of /a/ at 266 ms in /CV/ syllables and 127 ms in /CVC/ syllables. Similar patterns are found in Greek (Chaida et al., 2017) and Dutch, where short vowels average 82 ms in open syllables versus 51 ms in closed syllables, and long vowels 178 ms versus 124 ms

(Jongman, 1998). Articulatory data from Korean further show that vowels in open syllables (CVCV#) exhibit greater displacement and longer gestural timing than those in closed syllables (CVCVC#), reflecting expanded and slower articulatory gestures (Kim, Kim & Cho, 2024). One aim in the present study is to investigate the closed syllable shortening hypothesis in /CV.N/ vs. /CVN/ sequences in Modern Standard Arabic.

Preboundary lengthening is a phonetic cue to prosodic phrasing that has been documented in different languages (e.g. Maiteq, 2013; Beckman & Edwards, 1990; Cambier-Langeveld, 2000; Klatt, 1973; Lehiste, 1970; Turk & Sawusch, 1997; Turk & Shattuck-Hufnagel, 2007; Wightman et al, 1992; Maekawa, 1997). Beckman & Edwards (1990) showed that vowels undergo systematic preboundary lengthening, especially at stronger (e.g., intonation phrase) edges, providing a reliable acoustic cue to prosodic constituency and its demarcation. Turk & Sawusch (1997) show that accentual lengthening is localised to stressed syllables, while preboundary lengthening is a broader, cumulative cue to prosodic boundaries. Turk & Shattuck-Hufnagel (2007) provide timing evidence that preboundary lengthening scales with boundary strength, supporting a hierarchical model of prosodic representation. Wightman et al. (1992) show that preboundary lengthening scales with boundary strength, offering a clear acoustic cue for hierarchically organised prosodic structure.

Research on preboundary lengthening in different Arabic dialects provided evidence that vowel durations are predictable from prosodic structure and specifically boundary level (de Jong & Zawaydeh, 1999; Maiteq, 2013). For example, it has been reported that in Jordanian Arabic vowels are longer when they occur utterance-finally than non-utterance-finally (de Jong & Zawaydeh, 1999). Research on pharyngealisation across multiple prosodic boundaries in Libyan Arabic shows that preboundary vowel durations increase progressively from syllable, word, phrase and intonation phrase accompanied by a pause (Maiteq, 2013). Chahal (2001) investigated accented syllables vs non-accented syllables in domain-final positions in Lebanese Arabic: intonation phrase, intermediate phrase, and word. Chahal found longer durations for accented syllables before higher prosodic domains such as the intonation phrase than before lower ones. In the next section we discuss theoretical issues relevant to the present study, i. e., whether preboundary lengthening is gradient or categorical, and the domain of preboundary lengthening.

Theoretical considerations

A fundamental question in the present study is whether preboundary lengthening is categorical or gradient. Gradient effects peak in the vicinity of the boundary and attenuate with temporal distance, while categorical accounts posit distinct boundary-conditioned categories. Production and perception data from American English support categorical boundary effects (Krivokapić & Ananthakrishnan, 2007), whereas other studies are consistent with gradient patterns (Berkovits, 1993; Lunden, 2010; Seo et al., 2019). For example, Berkovits (1993) found that utterance-final fricatives in Modern Hebrew undergo greater lengthening than the stressed vowel preceding them. Gradient effects have also been reported in Japanese (Seo et al., 2019) and Korean (Kim et al., 2019). Cross-linguistically, the relative magnitude of preboundary lengthening tends to increase progressively across segments from left to right (Turk & Shattuck-Hufnagel, 2007). While such gradient aspects were once thought to be universal phonetic tendencies (Kingston & Diehl, 1994), their language-specific variability suggests they are part of the phonetic grammar of individual languages. Cambier-Langeveld (2000) demonstrates that preboundary lengthening is a gradient cue to prosodic constituency, modulated by boundary strength and overlapping with accentual effects. Maiteq (in press) examined vowel durations in /CVN/, /CV.N/, and /CV#N/ locations, and reported that preboundary /a/ is significantly longer when it is in word-final positions, with no significant increase in syllable-medial and syllable-final positions, yielding a categorical effect. Maiteq's results were interpreted as syllable boundaries are invisible to the preboundary lengthening process to which word boundaries are tied. Thus, extending Arabic data to a different vowel quality /i/ allows to further investigate the phonetic nature and domain of preboundary lengthening in Modern Standard Arabic.

Another theoretical issue concerns the domain of preboundary lengthening. In English, it has been shown to align with the syllable rime preceding the boundary (Wightman et al., 1992; Turk & Shattuck-Hufnagel, 2007). In Japanese, the domain is the mora (Seo et al., 2019), while in German it is the nuclear vowel of the stressed syllable (Shubo & Zerbian, 2023). For Modern Standard Arabic, Maiteq (in press) found that the word constitutes the domain of preboundary lengthening, based on analysis of /a/ in /CVN/, /CV.N/, and /CV#N/ structures. These findings highlight the language-specific nature of preboundary domains. The closed syllable shortening hypothesis discussed above is

directly relevant to the broader prosodic domain issue here in that a vowel at the edge of a syllable /CV./ is longer than when it is in the middle of the syllable /CVC/. In English, for example, the vowel in /see/ is longer than that in /seed/ or /seat/ (Jones, 1950, cited in Maddieson 1984: 93).

Building on observations of vowel duration variation due to segmental properties (Keating, 1984), syllable structure (Maddieson, 1984), and prosodic effects in Arabic (Chahal, 2001; Jong & Zawaydeh, 1999; Maiteq, 2013; Maiteq, in press), Japanese (Seo et al., 2019), English (Wightman et al., 1992; Turk & Shattuck-Hufnagel, 2007), and Dutch (Cho & McQueen, 2005), this study investigates preboundary lengthening of the high vowel /i/ in Modern Standard Arabic, focusing on presence/absence of syllable boundary (/CVN/, /CV.N/), and on the word (/CV#N/) boundary.

Predictions

It is hypothesised that vowel duration will vary systematically with boundary strength. The shortest duration is expected in the closed syllable condition (/CVN/), consistent with the closed syllable shortening hypothesis. A slight increase is predicted in the syllable-boundary condition (/CV.N/), while maximal lengthening is expected in the word-boundary condition (/CV#N/). A progressive increase across these three conditions would support a gradient account, whereby vowel duration gradually increases from syllable boundary to word boundary, as compared to no boundary in the closed syllable condition. Alternatively, if lengthening occurs only at the strongest boundary, i.e., the word boundary, this would support a categorical account of preboundary lengthening tied specifically to word-final position.

Method

This study follows an experimental acoustic approach. Carefully controlled acoustic data were designed, collected and analysed in order to provide answers to our research questions.

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 /V/ was always /i/ and /N/ was a nasal consonant /n/ or /m/. The selected tokens were intended to render a hierarchy of prosodic boundary strength: zero-boundary in closed syllable (CVN), syllable boundary with an open syllable (CV.N), and word boundary with an open syllable at the end of the word (CV#N). All target vowels were unstressed in order to control for the stress factor. Number of tokens obtained for the present experiment is (141 for /CVN/ + 147 for /CV.N/ + 75 for /CV#N/, total number of tokens = 363).

Table 1: Target sequences embedded in three prosodic locations (/CVN/; /CV.N/; /CV#N/.

Position	Structure	Word	Gloss
Syllable-Medial	/CVN/	mintʿaqa	'area'
Syllable-Final	/CV.N/	lakinaha	'but (it)'
Word-Final	/CV#.N/	arbaʂi # manatʿiqa	'four areas'

Acoustic measurements of vowel duration were carried out using Praat software for speech analysis (Boersma & Weenink, 2025), 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 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.

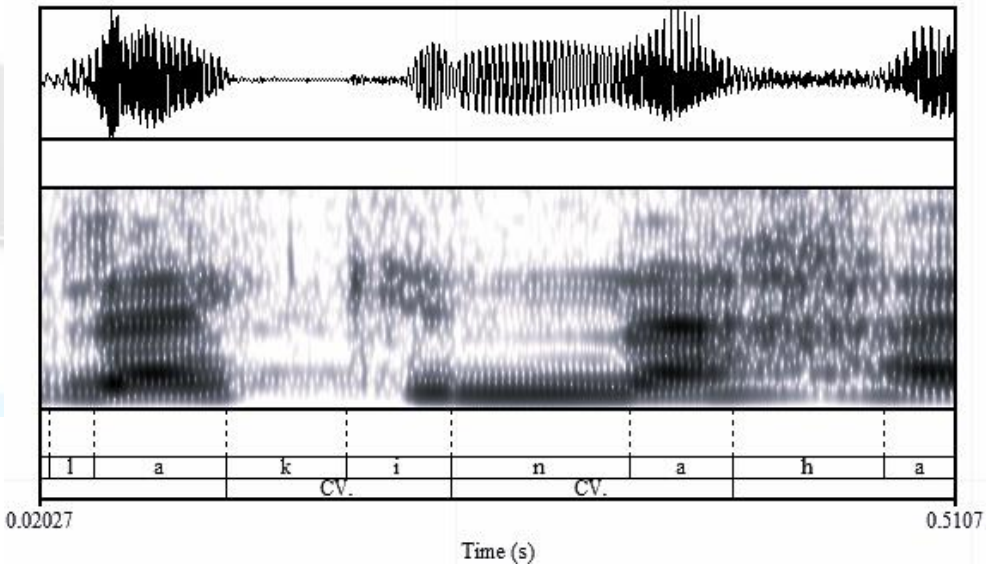

Figure 1: A portion from the word /ˈlakinaha/ 'but (it)', showing a syllable-final /i/ vowel (/CV./ corresponding to the underlined /ki/). The VOT interval is part of the vowel.

Data Analysis

A total number of 363 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 ration test using the anova function in R. The best-fit that converged was constructed with vowel duration as the dependent variable, prosodic position as a fixed independent variable (with the Syllable-medial condition as a reference level). Random intercepts for Speaker and Word were included in the random structure of the model.

Results

In order to answer our research questions, duration measurements were submitted to linear mixed effects analysis. Model results are presented in Table 2 and Table 3, and visualized in Figure 2.

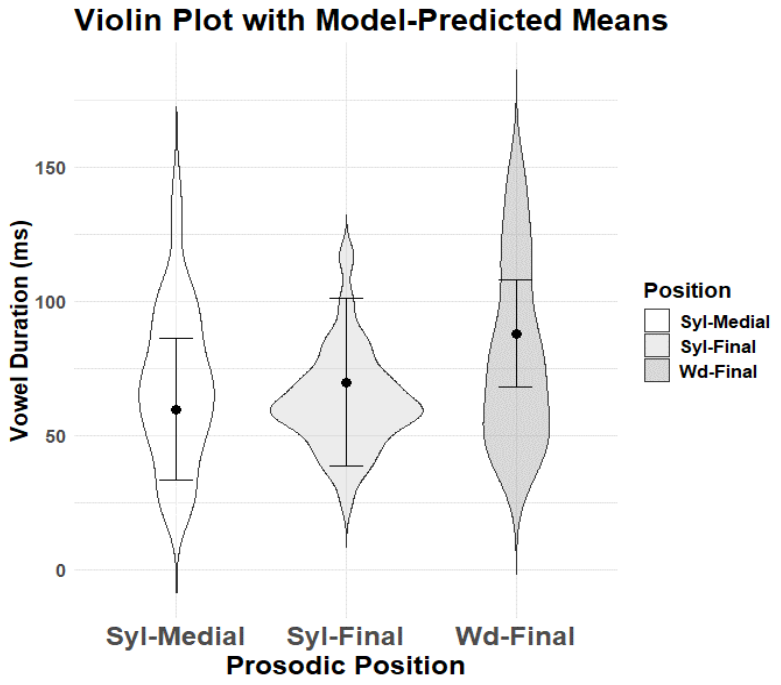

Figure 2: Visualisation of the predicted data in the model shows three-way duration distinction. The mean values are represented in the black dot.

Results in Table 2 – Table 3 and Figure 2, show that the intercept, referring to vowel duration in the syllable-medial position /CVN/, is 59.7 ms (p = 0.05). The syllable-medial coefficient shows that vowel duration in /CV.N/ structures increased by 10.027 ms, yielding a vowel duration (59.656 +10.027 = 69.893 ms, p = 0.01). The Word-final coefficient shows that vowel duration at the end of the word /CV#N/ increased by 28.237 ms, yielding a vowel duration (59.656 + 28.237 = 87.893, p = 0.001). These results show that vowel duration progressively increased as function of boundary strength (/CVN/; /CV.N/, and /CV#N/). This shows that the hierarchical strength of prosodic boundaries is phonetically manifested in vowel duration.

Table 2: Predicted vowel duration values for the /i/ vowel in three prosodic positions: (syllable-medial /CVN/; syllable-final /CV.N/; word-final /CV#N/).

Random effects					
Groups Name	Variance	Std. Dev			
Word (Intercept)	671.63	25.916			
Speaker(Intercept)	19.05	4.365			
Residual	85.78	9.262			
Fixed effects					
	Estimate	**Std. Error**	**df**	**t.value**	**P-value**
(Intercept)	59.656	4.423	1.510	13.489	0.05
Syllable-Final	10.027	3.254	353.397	3.082	0.01
Position Word-Final	28.237	4.201	344.817	6.721	0.001

Table 3: By-hand model coefficient computation as outlined in Winter (2020).

Prosodic Position	Coefficient Computation	Predicted Duration (ms)	P-value
Syllable-medial [CVN]	59.656	59.656	0.05
Syllable-final [CV.N]	59.656 + 10.027	69.683	0.01
Word-final [CV#N]	59.656 + 28.237	87.893	0.001

The random effects in the model show that the variance associated with by-word random intercept is 671.63 (SD = 25.916). The variance associated with by-speaker random intercept is 19.05 (SD = 4.365). These random effects results suggest that the choice of words contributed far more to vowel duration variability than speakers.

Generally, these findings suggest that preboundary vowel duration progressively increased with boundary strength, from no-boundary /CVN/ to syllable boundary /CV.N/ to word boundary /CV#N/. These results provide evidence that the /i/ vowel was shortest within the syllable, longer across the syllable boundary, and longest across the word boundary. The present results are consistent with a closed syllable shortening hypothesis. They also show that the syllable serves as the domain of preboundary lengthening, with gradually increasing magnitude with temporal proximity to the word boundary.

Discussion

The present findings demonstrate that preboundary lengthening increases progressively with boundary strength, yielding a three-way durational distinction (zero boundary /CVN/ < syllable boundary /CV.N/ < word boundary /CV#N/). This pattern supports previous accounts that preboundary lengthening functions as a low-level phonetic cue signalling high-level prosodic structure. Prior data from Modern Standard Arabic (Maiteq, in press) showed that preboundary lengthening of the low vowel /a/ was tied

specifically to word boundaries, with no significant effect at syllable boundaries. By contrast, the current results reveal that the high vowel /i/ is modulated in a strictly progressive manner, reflecting a hierarchical increase in boundary strength. These findings suggest that vowel lengthening is shaped not only by prosodic boundary strength but also by inherent vowel properties, as noted by Keating (1984), Lehiste (1970), and Lindblom (1967). Taken together, these results provide further support for the closed-syllable shortening hypothesis (Maddieson, 1984).

The present findings indicate that preboundary lengthening in Modern Standard Arabic is gradient, consistent with findings on Japanese (Seo et al., 2019) and Korean (Kim et al., 2019), and hierarchical, with measurable effects at both the syllable and word levels. Vowel durations increase cumulatively from zero-boundary /CVN/ through syllable-final /CV.N/ to word-final positions /CV#N/, suggesting that the syllable serves as an operative domain within a larger prosodic hierarchy. This domain pattern contrasts with English and Japanese, where lengthening has been attributed primarily to the rime in English (e.g., Turk and Shattuck-Hufnagel, 2007) or mora in Japanese (e.g., Kubozono, 2017; Seo et al, 2019), and aligns more closely with languages such as Modern Hebrew that exhibit word-level effects (Berkovits, 1993). Arabic thus demonstrates a layered prosodic organisation, in which syllable-level lengthening contributes to, but does not exhaust, the domain of boundary-related timing adjustments.

Generally, these findings suggest that preboundary lengthening in Modern Standard Arabic is prosodically modulated, consistent with the hierarchical organisation of prosodic structure. 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 syllable domain of preboundary lengthening.

Conclusion

The findings demonstrate that preboundary lengthening is conditioned by prosodic boundary strength in Modern Standard Arabic in a gradient fashion, consistent with the hierarchical organisation of prosodic structure. The syllable serves as an operative domain of preboundary lengthening, highlighting a language-specific phonetic implementation of high level prosodic structure. Taken together, these findings reveal that prosodic boundary

strength is phonetically cued in Modern Standard Arabic, providing insight for ongoing discussions on the phonetics-prosody interface. Further research on Arabic is needed to include higher prosodic boundary types such as the intermediate phrase and the intonation phrase, as well as other prosodic factors such as stress and prominence.

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