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Utterance-final lengthening in Thai: A preliminary report*

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Park, Kyung-Eun and Tae-Yeoub Jang. 2024. Utterance-final lengthening in Thai: A preliminary report. *Linguistic Research* 41(3): 635-659. Utterance-final lengthening is a well-documented cross-linguistic phenomenon. While previous studies have noted its presence in Thai, systematic and empirical investigations remain limited. This study addresses this gap by conducting an acoustic analysis of utterance-final lengthening in Thai, using data produced by native speakers. Four frequently occurring polysemous Thai words—'dai' /dâːj/, 'hai' /hâj/, 'pen' /pen/, and 'laeo' /lɛ́ːw/—were selected and embedded in sentences designed to place them either medially or finally. These sentences were produced and recorded by twenty-one speakers of central Thai. Acoustic measurements and statistical analysis of the relevant speech tokens revealed that word rime durations in utterance-final positions were, on average, 3.5 times longer than in medial positions. The lengthening effect in final positions was so substantial that it considerably masked the temporal difference between function and content words. Interactions with other factors, such as vowel length, lexical tone and word type were also examined. These findings are expected to provide preliminary information on Thai utterance-final lengthening, contributing to the prosodic analysis of Thai and offer insights for cross-linguistic typological research. **(Hankuk University of Foreign Studies)**

Keywords Thai, tempo, utterance-final lengthening, pre-pausal lengthening, preboundary lengthening, Thai speech

1. Introduction

The tendency to lengthen the final element of an utterance has been widely observed

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and well-documented across many languages, including English (Oller 1973; Klatt 1975; Gussenhoven and Rietveld 1992; Shattuck-Hufnagel and Turk 1998; Turk and Shattuck-Hufnagel 2007; Byrd and Riggs 2008; Kim et al. 2017; See Fletcher 2010 and Cho 2015 for a further review), German (Kohler 1983, Schubö and Zerbian 2020), French (Fletcher 1991), Finnish (Nakai et al. 2009), Italian (Petrone et al. 2014), Greek (Katsika 2016), Czech (Spina and Schubö 2021), Estonian (Krull 1997), Russian (Kachkovskaia et al. 2013), Hungarian (Hockey and Fagyal 1998; White and Mády 2008), Vietnamese (Ingram and Nguyen 2003), Japanese (Campbell 1992, Shepherd 2008), Mandarin (Li 2024), Cantonese (Chow 2008) and Korean (Jang and Katsika 2020). The widespread occurrence of this phenomenon has led researchers to consider it a universal feature of spoken language (Vaissière 1983, among others). Seifart et al. (2021) further reinforce this universality of utterance-final lengthening by presenting cross-linguistic evidence from investigations of nine under-resourced languages, along with Dutch, showing that utterance-final words across these languages consistently have longer durations than utterance-medial words, despite language specific variations in the degree and domain of lengthening. The universality of this lengthening can be attributed to language-independent effects of the human speech production mechanism. In this context, Byrd and Saltzman (2003: 160) introduced the concept of the "π-gesture," which acts as a signal prompting the articulators to slow down or extend their movements to emphasize prosodic units, ultimately aiding listeners in perceiving breaks in speech.

In Thai, lengthening of syllables in utterance-final or pre-pausal positions has also been noted. Hansakunbuntheung et al. (2003) observes that syllables at the end of words or phrases in Thai utterances are subject to lengthening. Shi et al. (2021) examined speech produced by L2 Mandarin learners from three different L1 backgrounds: English, Japanese and Thai. They found that Thai learners of Mandarin extended the rime of the preboundary syllable considerably more than English and Japanese learners, suggesting that this may be attributed to characteristics of spoken Thai. However, to the best of our knowledge, there has been no report of systematic, quantitative measurement of the extent and variability of this lengthening. To address this gap, we aim to provide preliminary but systematic information on the utterance-final lengthening in Thai speech.

In addition to boundary-related position, several factors may influence the duration of the rime or syllable, potentially masking or amplifying the positional effect. These

factors include the segmental context, syllable structure, speaker's speech rate, lexical prosody (such as tone and stress), and vowel length. To examine the effect of utterance-final lengthening, it is necessary to either control for features that influence speech tempo to isolate their effects or consider them alongside the main feature, i.e., the boundary-related position. In this study, segmental structures, such as segmental context and syllable structure, are controlled, while prosodic features like tone and vowel length are analyzed to assess their approximate effects.

In order to fix the segmental structure of target words, in this study, the characteristics of Thai word formation were utilized. It is widely accepted that historically, all lexical entries in Thai were content words. To expand its vocabulary, Thai has actively employed polysemy alongside compounding and other word-formation processes. This has led to the extension of meanings for certain words through grammaticalization (Sriprasit 2003; Thepkanjana and Uehara 2008; Pantumeta 2016; Thepkanjana 2016). For example, the polysemous verb 'dai' ('ได้' /dâːj/) functions as a transitive verb meaning 'to obtain' when used as the main verb. However, when it precedes certain verb phrases, it acts as an auxiliary verb to express the 'perfective aspect'. Additionally, when following other verb phrases, it serves as a subsidiary verb indicating 'ability', 'possibility' or 'permission'. By selecting polysemous words in Thai, i.e., words that have the same segmental and word-internal prosodic structure but different meanings or functions, a script for voice production can be created to effectively control for most lexical-level segmental and prosodic structure variability. Of course, it is not feasible to select only a single word as the target vocabulary. To understand the interaction between the main phonological characteristics of Thai and the positional effect, it is necessary to examine words with diverse features as target vocabulary. In this study, four different polysemous words are used, and their temporal information will be pooled and collectively compared. However, to maintain control for segmental structure, it is essential to select words that are as homogeneous as possible in their segmental structure.

The first relevant feature we will examine in this study, which may influence utterance-final lengthening is phonemic vowel length. Previous research on how phonemic vowel length contrast affects boundary-related lengthening has shown inconsistent results across different languages. White and Mády (2008) found that in Hungarian, the proportion of lengthening of monosyllable words with a long vowel in the final syllable as compared to those in the medial position is comparable to

those with short vowels while the magnitude of lengthening is greater in long vowels. It implies that there was no significant interaction between vowel quantity and preboundary lengthening. On the contrary, Spina and Schubö (2021) reported that in Czech, which is a language with a contrastive vowel length, both short and long vowels undergo preboundary lengthening at the final syllable. But the proportion of lengthening on short vowels was larger than long vowels at this position. They suspected that this result is due to a ceiling effect: Long vowels might not have as much room for lengthening as short vowels do before a maximum level is reached. Therefore, it is meaningful to examine whether there is any interaction between vowel length and utterance-final lengthening. Shepherd (2008) analyzed the lengthening effect of immediately preboundary vowels in Japanese and reported that the proportion of lengthening is greater for short vowels. He added that this is because, in Japanese, the π-gesture associated with intonation phrase boundaries has a preboundary temporal scope of approximately one mora. This duration is sufficient to overlap an entire short vowel (and the preceding consonant) but only covers the latter portion of a long vowel. In light of the findings from these previous studies, it can be concluded that the effect of phonological vowel length on preboundary lengthening varies across languages. Thus, it seems necessary to analyze how this phenomenon occurs in Thai, another language that features a phonological vowel contrast. In this study, we analyzed the interaction between the effect of position and vowel length.

Lexical tones are another feature closely related with temporal characteristics including utterance-final lengthening. Zahng (2004) mentions the role of contour tones in licensing lengthening for syllables in phrase-final positions. More recent studies (Li et al. 2023; Li 2024) reported that preboundary lengthening in Mandarin Chinese is influenced by lexical tones, with greater temporal expansion observed for complex tones like Tone 3 (low-dipping) and Tone 4 (falling) compared to simpler Tone 1. This finding suggests that complex tones may better realize temporal expansions than simplex tones. Presumably, a longer time is required for the realization of the complex Tone 3 and Tone 4. Based on this insight, we will analyze whether a similar difference in lengthening occurs when words with simple and complex tones, which also exist in Thai, are located at the end of an utterance. However, it should be noted that this study does not examine all five tones of Thai-namely mid[33], low[11], falling[52], high[45] and rising[24] tones,[1] as the selection of target words prioritized other factors such as polysemy and frequency.

The last key factor to consider in this study is the temporal change according to word type. In languages with a stress-based rhythm, such as English, it is common for function words to have shorter durations than content words due to the lack of accent or focus at the utterance level (Roach 1982; Dauer 1983). Although it is difficult to conclusively determine whether Thai has a stress-based or syllable-based rhythm, researchers (Luangthongkum 1977; Grabe and Low 2002; Sarmah et al. 2009) suggest that conversational Thai follows a stress-based rhythm. Consequently, Park and Jang (2022) analyzed whether function words in Thai exhibit function word shortening, reporting statistically significant but modest shortening effects. As the polysemous words analyzed in this study can function as either content words or function words depending on the context, it is meaningful to explore how this factor might influence utterance-final lengthening. Specifically, when function words, which are prone to shortening due to their word type, occur at utterance-final positions where lengthening takes place, these two processes could conflict. This study attempts to analyze the extent to which the shortening effect might offset the boundary-related lengthening.

In brief, this study examines whether preboundary lengthening, which has been discussed and verified in previous research for many languages, occurs at the right boundary of the highest prosodic unit, the utterance, in Thai. If it does, the study will explore the extent of its occurrence. Additionally, the study will investigate how factors such as vowel length, tone, and word type, which influence the duration of various speech units, affect utterance-final lengthening.

2. Experiment

2.1 Selecting target words

Four polysemous Thai words—'dai' /dâːj/, 'hai' /hâj/, 'pen' /pen/, 'laeo' /lɛ́ːw/—were selected based on the following criteria. First and foremost, each word must exhibit polysemy, meaning it should have multiple distinct meanings or usages. This includes

1 The numerical tonal markings represent the relative F0 contour, following the guidelines of the Ministry of Education of Thailand (Thai Language Institute, Office of Academic and Educational Standards, Office of the Basic Education Commission, Ministry of Education 2019).

cases where the word serves different grammatical functions but excludes instances where the base meaning remains consistent through derivation or compounding. For example, if a word functions as a main verb in one context and as an auxiliary verb in another, it is considered polysemous unless the meanings in both contexts are directly related. Secondly, each word must be frequently used by Thai speakers. By selecting words ranked within the top 20 in the Thai National Corpus (TNC), we aim to minimize the potential influence of frequency on spoken word duration. Thirdly, each word must be homophonous, meaning its basic phonological structure—including segments and prosody—remains consistent across different usages. Since Thai is a language with contrastive tones and vowel lengths, controlling for these factors is crucial to accurately analyze temporal variations without confounding effects. Table 1 presents the four selected words and their properties.

Table 1. Four polysemous target words. For convenience, the romanized form of each word will be used throughout this paper. The numerical tonal markings in the final column represent the relative F0 contour, following the guidelines of the Ministry of Education of Thailand.

	Word (romanized)	Word (Thai)	IPA	Vowel length	Lexical tone [type]
1	dai	ได้	dâːj	long	complex (falling [52])
2	hai	ให้	hâj	short	complex (falling [52])
3	laeo	แล้ว	lɛ́ːw	long	simple (high [45])
4	pen	เป็น	pen	short	simple (mid [33])

The segmental structure of the four selected words is consistent, in that they are all monosyllabic, ending with a sonorant or approximant sound. While these words differ in their lexical tones, each polysemous pair maintains a uniform tonal property. Therefore, if differences in utterance-final lengthening are observed across these words, it is crucial to investigate whether these variations are due to the different lexical tones. Additionally, it is important to assess whether the contrastive vowel length in Thai influences final lengthening.

The selection of monosyllabic words for this experiment is not arbitrary. Thai, being an isolating language, primarily consists of monosyllabic words and compounds, with no inflectional affixation. This characteristic is advantageous for studying

lengthening effects, as it reduces the need for unnatural or overly strict word selection controls.

Sentences were constructed to position each target word either medially or finally, as shown in Table 2. Note that there are three homogeneity groups based on two combined factors: Word Type (Content or Function) and Position (Medial or Final). For instance, "CM" refers to a content word located utterance-medially. The combination "CF" (Content word in Final position) is intentionally excluded, as it would often result in unnatural sentences in Thai. For example, the target words 'hai', 'dai', and 'pen' typically function as transitive verbs when used as content words. Since Thai transitive verbs generally require an object, placing them at the end of an utterance would frequently produce sentences lacking an object.

It is also notable that placing target words at the beginning of a sentence was avoided to prevent complications associated with domain-initial strengthening (Cho and Keating 2001).

Table 2. Sentences containing target words. The romanization is based on the 'Royal Thai General System of Transcription' published by Office of the Royal Society in 1999. (http://legacy.orst.go.th/wp-content/uploads/2015/03/416_2157.pdf). CM=Content word, Medial position, FM=Function word, Medial position, FF=Function word, Final position

	Word	Group	Target words in sentences (IPA transcription)
1	'hai' /hâj/ **ให้**	CM	kʰruː **hâj** kʰànǒm dèk dèk
		FM	pʰîːsăːw sɯ́ː kràʔpăw **hâj** kʰunmɛ̂ː
		FF	tɕʰăn tɕàʔ sɔ̌ːn pʰaːsăːtʰaj **hâj**
2	'dai' /dâːj/ **ได้**	CM	miː naː **dâːj** kʰâː kʰànǒm wan láʔ rɔ́ːj bàːt
		FM	miː naː **dâːj** tɕʰim ʔaːhăːn kawlîː
		FF	kʰăw pʰûːt pʰaːsăː kawlîː **dâːj**
3	'pen' /pen/ **เป็น**	CM	pʰaːsăː tʰaj **pen** pʰaːsăːmɛ̂ː kʰɔːŋ sǒm rák
		FM	máʔlí pʰûːt pʰaːsăː tʰaj **pen** pʰaːsăːmɛ̂ː
		FF	kʰun sôm kʰàp rɯa **pen**
4	'laeo' /lɛ́ːw/ **แล้ว**	CM	kʰroːŋkaːn săːmâːt **lɛ́ːw** sèt dâːj pʰaːjnaj piː níː
		FM	láːŋ mɯː hâj sàʔàːt **lɛ́ːw** paj taːm nɔ́ːŋ maː kin kʰâːw
		FF	kʰăw tʰam kaːn bâːn sèt **lɛ́ːw**

2.2 Recording

Twenty-one Bangkok Thai speakers (four male and seventeen female), all in their twenties or thirties with no reported speech impairments, participated in the study. They read a pseudo-randomized sentence list where each target sentence appeared twice. The speakers were instructed to read every sentence as a single Intonation Phrase (IP) or at least without inserting any pauses. If they failed to do so on the first attempt, they were asked to repeat the reading. This request ensured that, in this study, the cause of the lengthening effect was confined to the right edge of the utterance, the highest level in the prosodic hierarchy.

Speech recordings, initially captured on each speaker's mobile device or PC, were converted to a uniform digital format with 44 kHz sampling and 16-bit quantization. A total of 504 utterance tokens (4 words × 3 groups × 2 iterations × 21 speakers) were prepared for analysis, excluding 36 dummy sentences included in the sentence prompt.

2.3 Segmentation and labeling

For the final pre-processing step, segmentation and labeling at the lexical and phone-like unit levels were initially performed using a DNN-based forced alignment tool for all utterance tokens. Subsequently, one author of this paper, along with two phonetics-trained students, reviewed the automated labels and manually adjusted boundary demarcations as needed. All manual adjustments were made using Praat (v.6.4.17, Boersma and Weenink 2024), a publicly available speech analysis tool.

2.4 Measurement

A Python script was created to automatically measure the duration of relevant sections within each syllable. In this study, we focused on measuring the duration of the 'rime'—the peak vowel and the following coda consonant—rather than the total duration of the final syllable, for the following reasons.

First, accurately measuring the duration of onset consonants can be challenging, especially when a syllable begins with a stop consonant, where silence is difficult to

discern. This issue may be mitigated when the word occurs within a sentence spoken without a pause before the target word. However, the reduction of onset consonants in fast speech can still obscure the determination of accurate consonantal boundaries. Second, and more importantly, previous research has reported inconsistent findings regarding the extent of the final lengthening effect in the syllable unit. While Jang and Katsika (2020) suggest that final lengthening extends to the onset of the final syllable, Klatt (1976: 1211) describes that most of the durational increment of the pre-pausal syllable is restricted to the vowel and any postvocalic sonorant or fricative consonants. Also, other studies have shown that the phrase-final rime is the most reliable and primary domain for this lengthening effect (Cambier-Langeveld 1997; Byrd and Riggs 2008; Katsika 2016; Kim et al. 2017). Even some studies, such as those on Czech, have reported compensatory shortening of onset consonants as a result of lengthening in the rime (Jang and Katsika 2020; Spina and Schubö 2021). The current study does not aim to resolve the issue of whether the onset of the final syllable adjacent to the boundary falls within the range of final lengthening or even it undergoes the compensatory shortening. Third, the syllable onset does not appear to play a significant role in prosodic processes in Thai. Sirintranon and Hsieh (2024: 242) point out that, unlike in English, only "rimal properties" such as vowel length, vowel lowness, and coda sonorancy contribute meaningfully to the determination of syllable weight in Thai. They add that this is related to the fact that the onset is not considered a tone-bearing unit, despite lexical tone being a major prosodic feature in Thai.

Based on these previous investigations on the domain of lengthening, despite some variations that are likely due to language-specific factors and differences in speaking style, measuring rime duration is considered a more reliable, factor-neutral method for investigating utterance-final lengthening. Figure 1 illustrates an example of rime duration measurement used in this study.

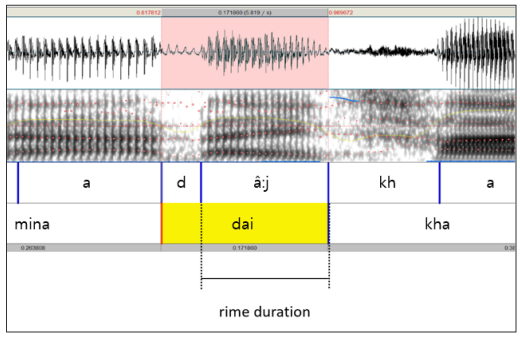

Figure 1. Example of a rime section

Research has shown that the utterance-final lengthening effect often extends beyond the final syllable directly adjacent to the boundary. In many languages, this effect can extend to the penultimate syllable, particularly when the preboundary word is multisyllabic (Flege and Brown 1982; Turk and Shattuck-Hufnagel 2007; Byrd and Riggs 2008). However, this consideration does not affect the current experiment, as all target words are monosyllabic.

Of course, future studies should analyze multisyllabic words that exist in Thai to examine lengthening effects beyond the syllable level and the domains extending beyond word boundaries.

2.5 Analysis

In this experiment, each speaker produced each sentence twice to ensure a sufficient number of data tokens, which makes it difficult to claim strict data independency. Therefore, instead of applying a traditional linear regression model, it is considered more appropriate to employ a mixed-effects model designed with random intercepts for each speaker to account for this factor. The variance-covariance specification of this model is known to capture this type of non-independence (or, asphericity) between observations (Baayen et al. 2008).

Table 3 presents the structure of variables used to fit a linear mixed-effects model.

Table 3. The structure of variables used for the mixed-effects modeling

		Variables (values)
Response		Duration of target word rime (milliseconds)
Predictor	Fixed effects	Position (final, medial) Vowel length (long, short) Lexical tone (simple, complex) Word type (function, content) Interactions of Position & Vowel length Interactions of Position & Lexical tone
	Random effects	Speaker, Speech rate, Sentence item

As shown, the response variable is the Rime Duration (in milliseconds) of each target word. Among the predictors, the fixed effects include Position, along with categorical variables such as Vowel Length, Lexical Tone, and Word Type, which are expected to influence temporal characteristics of words. In addition, we examined interactions between fixed effects in two specific cases: Position and Vowel Length, and Position and Lexical Tone. The interaction between Position and Word Type was not included as a predictor variable due to a 'rank deficiency' that arose during modeling. This deficiency suggests possible collinearity between certain unknown variables, but does not indicate any serious issues with the data. Consequently, the results of the interaction between Position and Word Type are analyzed separately in a later section.

Regarding the random effects setting, with the current experimental design, it is not appropriate to assume that the explanatory variables have a large effect on the response variable, which is Rime Duration, for a specific group of data tokens. Therefore, the random intercepts model, instead of a random slopes model, was fit assuming the same slope for each data group. In fact, the model did not converge when tested with random slopes, resulting in a singular fit, possibly because the correlation between the slopes and intercepts is estimated close to |1|. This indicates that the model has been over-parameterized (Baayen et al. 2008: 395).

Major procedures for these statistical analyses were conducted using R (R Core Team 2024. v.4.4.1.) and its package 'lme4' (Bates et al. 2015).

3. Results and discussions

The overall result of mixed effects model can be summarized in Table 4 for fixed effects and Table 5 for random effects.

Table 4. Estimates of fixed effects on rime duration in millisecond (msec). All values are rounded to one decimal point except the p-value. (Statistical significance: p <.001***, .01**, .05*)

Formula:
lmer(duration ~ position + vowelLength + tone + wordType + position*vowelLength + position*tone + (1|speaker) + (1|speechRate) + (1|sentence), data, REML=FALSE)

	Estimate	SE	df	t	p	Sig
(Intercept)	441.6	8.7	35.5	50.7	<.001	***
position medial	-319.2	7.6	24.0	-42.2	<.001	***
vowelLength short	-80.8	6.8	24.1	-11.9	<.001	***
tone simple	-11.4	6.8	23.9	1.7	0.105	
wordType functionWord	-15.2	4.8	23.5	-3.2	0.004	**
position_mid:vowelLength short	84.1	8.3	24.0	10.2	<.001	***
position_mid:tone simple	21.4	8.3	23.6	2.6	0.016	*

As shown in Table 4, all fixed effects variables, except for Tone, were found to be associated with the duration of the final rime. Even for Tone, which is not independently related to lengthening, its interaction with Position was significant. For variables such as Vowel Length, Tone, and Word Type, their interaction with Position is more important than their individual roles. For instance, although an average difference between long and short vowels is generally anticipated, it is essential to investigate how each affects lengthening in the utterance-final position. Consequently, these interactions will be analyzed and discussed in detail in the following sections.

Table 5. Estimates of random effects on rime duration. All values are rounded to one decimal point.

Number of observations: 504 Groups: rate, 232; sent, 24; speaker, 21			
Groups	Name	Variance	Std.Dev.
speechRate	(Intercept)	159.7	12.6
sentence	(Intercept)	3.0	1.7
speaker	(Intercept)	386.4	19.7
Residual		1711.1	41.4

Regarding the estimation of random effects in Table 5, the two speaker-related variables such as 'speaker' and 'speech rate,' have relatively large variances in comparison with the sentence type, implying that the magnitude of lengthening is not consistent among speakers. Based on these results, the analysis related to the major effects will be explained in detail in the following sections.

3.1 Overall lengthening effects

For each of the four target words, as illustrated in Table 6 and Figure 2, the utterance-final lengthening effect is consistently observed. When positioned at the end of an utterance, the rime of the final syllable in each word is elongated approximately 3.5 times, from 111 msec to 392 msec. It is also shown that the lengthening effect applies regardless of whether they are used as function words or content words.

Compared to previous studies on utterance-final syllable lengthening in other languages, the magnitude of lengthening observed in Thai is notably large. For instance, Klatt (1976) reported an increase of about 60-200 msec, Delattre (1966) observed up to 75% extension in English, Spanish and German, Oller (1973) found approximately 100 msec of lengthening for both stressed and unstressed English vowels, and Flege and Brown (1982) reported an 89%, or 71 msec, increase for final unstressed syllables. Given the variability in experimental settings and language-specific factors across these studies, it is difficult to generalize the extent of final syllable elongation universally. The data format used in this study, i.e., separate utterances, may have contributed to the extensive lengthening observed, as compared to prior research that primarily examined spontaneous speech tokens. Nevertheless, the degree

of lengthening in Thai appears to be exceptional requiring further investigation into its underlying causes.

Table 6. Rime duration (mean and standard deviation in milliseconds) of words in different positions

		Utterance medial	Utterance final	Ratio of increase (final/medial)
Each word	dai	108 (27)	438 (89)	4.07
	hai	105 (33)	357 (63)	3.40
	laeo	112 (36)	427 (75)	3.82
	pen	120 (26)	346 (56)	2.88
Total		111 (31)	392 (82)	3.53

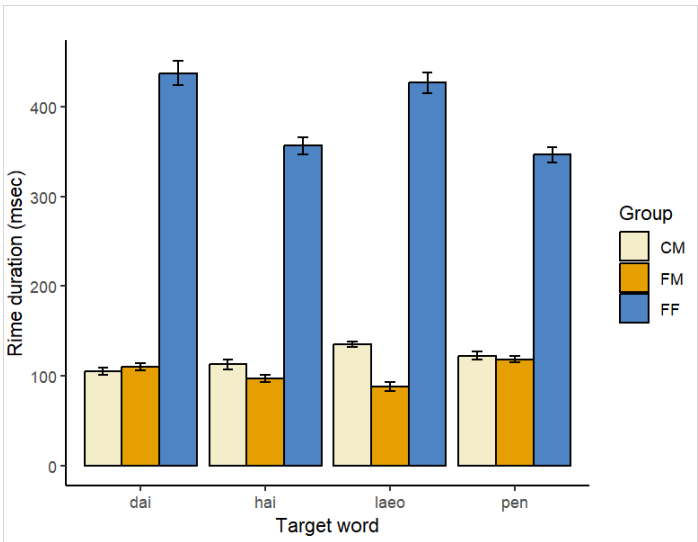

Figure 2. Visualized duration of each word with factors of 'Word Type' (content words / function words) and 'Position' (medial / final). For example, CF stands for the group of 'Content' words in 'Final' position.

As a result of the statistical analysis comparing two mixed effects models—one including the predictor 'Position' and the other excluding it—the difference was found to be highly significant ($\chi^2(1) = 120.6, p < .001$). This confirms that utterance-final

lengthening is evident in Thai. Further analysis will explore more specific effects, particularly the interaction between Position and other temporal features, as detailed below.

3.2 Vowel length

Analyzing the interaction between Position and Vowel Length revealed some intriguing results. As presented in Table 7 and Figure 3, while there was no significant difference between long and short vowels in the utterance-medial position, a clear distinction emerged in the utterance-final position, with the process of final lengthening being more pronounced for long vowels. As previously mentioned, studies have demonstrated diverse patterns of vowel length influence on preboundary lengthening in languages of vowel quantity contrasts, such as Hungarian (White and Mády 2008), Czech (Spina and Schubö 2021), and Japanese (Shepherd 2008). Specifically, Hungarian did not exhibit distinct lengthening based on vowel length, while Czech and Japanese showed greater lengthening for short vowels in final syllables. However, the current experiment presents a different result: durational stretching was greater for long vowels than for short vowels. This suggests that vowel duration alone may not consistently influence final lengthening. Instead, the language-specific linguistic properties of each language may interact to produce different patterns. To summarize, vowel length alone does not appear to be a universal factor influencing lengthening.

Table 7. Rime duration (mean and sd in msec) of words by 'Vowel Length' and 'Position' (p <.001***, .01**, .05*)

	medial	final***
short***	113 (30)	352 (60)
long***	110 (32)	432 (82)

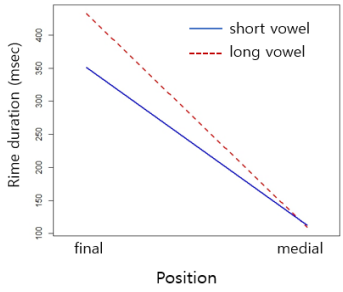

Figure 3. Interaction between 'Position' and 'Vowel Length'

3.3 Tone

Regarding the impact of lexical tones on final lengthening, Li et al. (2023) reported that preboundary lengthening in Mandarin Chinese is influenced by lexical tones, with greater temporal expansion observed for complex tones like Tone 3 (low-dipping) and Tone 4 (falling) compared to simpler Tone 1. This finding suggests that complex tones may better realize temporal expansions than simple tones. To explore whether a similar effect occurs in Thai, this study analyzes the target words based on two categories: simple tones (Mid, High) and a complex tone (Falling), selected from the five contrastive lexical tones in Thai.

As shown in Table 8 and visualized in Figure 4, a significant interaction effect is found between the variables Position and Tone (p = .016, see Table 4). When examining the proportion of lengthening, the rime with complex tones (374%) elongated more substantially than the rime with simple tones (333%). The trend is consistent with the findings for Mandarin Chinese observed by Li (2004) and Li et al. (2003).

Table 8. Rime duration (mean and sd in msec) of words by 'Lexical Tone' and 'Position' (p <.001***, .01**, .05*)

	medial**	final
simple***	116 (31)	386 (77)
complex***	106 (30)	397 (86)

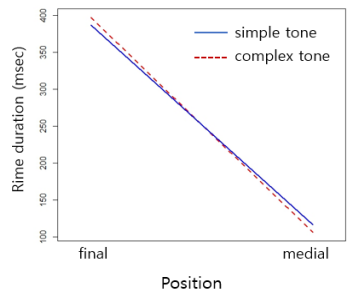

Figure 4. Interaction between 'Position' and 'Lexical Tone'

However, the perplexing part lies in the rime duration in the medial position. Contrary to expectations, the duration of complex tones was significantly shorter than that of simple tones. This discrepancy likely contributed to the larger increase in complex tones in the final position, suggesting that the results do not correspond with those found in Mandarin. It indicates that the interaction between Position and Tone requires further investigation with additional data.

One important consideration related to tone is the phenomenon called tone sandhi or tonal coarticulation, where phonological tones are phonetically altered by surrounding tones. In Thai, tone changes have been observed in unstressed syllables, particularly in prefixes of compound words (Hiranburana 1972; re-cited from Morev 2001: 102). For example, in the compound word /phɯ̂an.bâ:n/ (**เพื่อนบ้าน**, 'friend.home,' 'neighbor'), the tone of /phɯ̂an/ changes from falling (F0 contour [31]) to high (F0 contour [55]). Despite such specific variations, previous research has demonstrated that the five-tone system in monosyllabic words remains stable, regardless of the tones of preceding or following words (Abramson 1979: 7; Gandour et al. 1994). Although some distortion of tones may occur in continuous speech, it is generally not significant enough to hinder the identification of inherent tones. In this study, the target words are all monosyllabic and are not part of compounds, implying that their inherent tones remain unaffected by the tones of surrounding words. Consequently, tone sandhi is unlikely to have influenced the target words, regardless of their position in utterances. Future research should explore how final lengthening interacts with tone sandhi in compounds.

3.4 Word type

As previous research (Luangthongkum 1977; Grabe and Low 2002) has proposed, assuming that Thai rhythm is stress-timed, it is reasonable to expect that, similar to other stress-timed languages like English, Thai function words would undergo reduction and/or shortening. In a recent study on this topic, Park and Jang (2022) confirmed that statistically significant shortening of function words does occur. If these shortened function words are located in the utterance-final position, where lengthening typically occurs, a conflict between the two phenomena could arise.

As presented in Table 2, the data sentences in this study were constructed so that each polysemous target word appears in three evenly distributed environments, combining Word Type (content word, function word) and Position (medial, final): i.e., content-medial (CM), function-medial (FM), and function-final (FF). According to the overall mixed effects model in Table 4, Word Type was found to produce significant differences in duration, with function words being approximately 15 milliseconds shorter than content words. This difference was also confirmed in the

comparison between the CM and FM groups, where content words were found to be longer than function words by 17.5 milliseconds ($t(333.37) = 4.70$, $p < .001$).

The most interesting comparison is between the CM and FF groups. The CM group is in an environment least affected by lengthening or shortening, while the FF group is in an environment where utterance-final lengthening and shortening could conflict. Based on previous sections' results, it is anticipated that function word shortening is insufficient to significantly counteract final lengthening. This hypothesis is confirmed by the comparison between the CM and FF groups, as shown in Table 9 and Figure 5. When a function word is positioned at the end of an utterance, its duration is approximately 330% longer compared to when the corresponding content word is in the medial position ($t(213.3) = 40.3$, $p < .001$). This effect is observed across all four target words, with the word 'dai' showing the greatest relative increase (416%) and the word 'pen' showing the smallest (284%), as reported in Table 10 and visualized in Figure 6.

Table 9. Rime duration (mean and standard deviation in msec) of content words in medial position vs. function words in final position

	Content-Medial	Function-Final
mean (st.dv.)	118.9 (30.9)	392.0 (82.1)
median	120.0	390.0

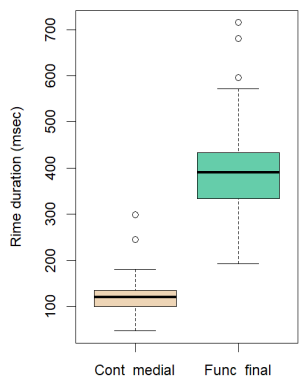

Figure 5. Boxplot of rime duration for content words in medial position and function words in final position

Table 10. Rime duration (mean and sd in msec) of each content word in medial position vs. corresponding function word in final position (p <.001***, .01**, .05*)

	Content-Medial	Function-Final
dai***	105 (28)	437 (89)
hai***	113 (37)	357 (63)
laeo***	135 (19)	427 (75)
pen***	122 (29)	347 (56)

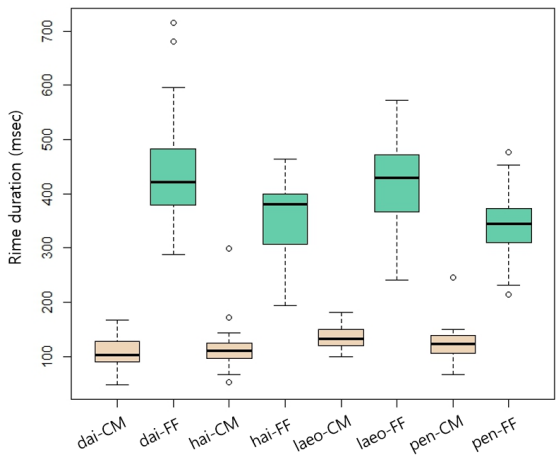

Figure 6. Boxplot of rime duration for each content word in medial position (CM) and corresponding function word in final position (FF)

In conclusion, the utterance-final lengthening in Thai is so strong that it almost preempts the effect of function word shortening. Thai is known for its ongoing process of word formation, especially through grammaticalization, where monosyllabic content words extend their usage as function words, leading to polysemy. This process occurs gradually, with some lexicons already in the later stages of grammaticalization while others are newly emerging. The complexity of this dynamic word formation process is expected to continue influencing the utterance-final lengthening in spoken Thai.

4. Summary and conclusion

It is clarified that utterance-final lengthening is certainly a prominent feature of Thai, with its magnitude considerably exceeding that observed in various other languages. The magnitude of this effect in Thai is so prominent that it can almost entirely mask the influence of word type. Specifically, function words placed at the end of an utterance exhibit much greater lengthening compared to homophonous content words located in the utterance-medial position.

Additionally, the study reveals that utterance-final lengthening interacts with other temporal factors, such as vowel length and lexical tones. Words or syllables containing long vowels and/or complex tones tend to lengthen more than those with short vowels and/or simple tones. However, it is evident that neither Vowel Length nor Lexical Tone appears to influence the extent of lengthening beyond the positional effect. More refined experimental settings seem necessary to confirm the interaction between utterance final lengthening and other temporal factors including Lexical Tone and Vowel Length.

It is necessary to consider the underlying reasons why utterance-final lengthening in Thai occurs on such a remarkable scale compared to other languages. The first reason to consider can be linked to the characteristic that the recording prompts used in this study were composed at the sentence level. All target words were positioned in the utterance-final position, where the right boundary of the utterance, the highest prosodic unit, aligns with lower units such as Intonational Phrase (IP) and Prosodic Word. There are observations that the lengthening effect becomes greater as the prosodic domain increases in hierarchical level (Wightman et al. 1992; Michelas and D'Imperio 2010). However, this reason alone cannot fully explain the exceptional final lengthening effect observed in Thai. Similar overlaps of prosodic domains frequently occur in other languages including English and French, yet those languages do not exhibit lengthening to the extent seen in Thai. Furthermore, some research presents conflicting results, indicating that a higher boundary does not significantly enhance the lengthening effect (Klatt 1975; Gussenhoven and Reitveld 1992).

Thus, a more compelling reason seems to be associated with the intrinsic characteristics of spoken Thai. In fact, like other Southeast Asian languages with contrastive lexical tones, Thai does not seem to employ stress as a significant phonological prosodic feature at the lexical level or higher levels (Haas 1964; Hyman

2014: 58). Nonetheless, recent research (Sirintranon and Hsieh 2024) has provided evidence that Thai also exhibits prosodic prominence akin to lexical stress, and this prominence invariably occurs in domain-final positions. Another significant report comes from the study by Potisuk et al. (1996), which experimentally demonstrated that the predominant acoustic correlate of stress-like prominence in Thai is duration. Given these findings, it can be inferred that the extension of duration triggered by the positional effect being analyzed is likely to be remarkably reinforced by another lengthening effect associated with stress-like prosodic prominence in Thai.

Assuming that Thai has not yet been systematically studied regarding boundary-related lengthening, this study aims to provide preliminary information by focusing on the boundary of the utterance, the highest level prosodic unit, and examining monosyllabic words to limit the domain to the preboundary syllable. The findings are expected to pave the way for further research on preboundary lengthening related to lower units, such as the Intonational Phrase, and to explore how far the effect stretches from the boundary location. Additionally, it will be valuable to investigate final lengthening in other understudied languages, including those with contrastive vowel length and lexical tones. Such investigations will contribute to a more comprehensive understanding of the phenomenon and its implications for language typology.

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