Journal of the International Phonetic Association (2024), **54**, pp. 264–293
doi:10.1017/S0025100323000233

ARTICLE

An exploratory investigation of interactions between syllabic prominence, initial geminates, and phrasal boundaries in Pattani Malay

Francesco Burroni[1, 2,†], Sireemas Maspong[1,2,†], Pittayawat Pittayaporn[2,*] and Pimthip Kochaiyaphum[2]

[1]Cornell University and [2]Center of Excellence in Southeast Asian Linguistics, Chulalongkorn University
[*]Corresponding author. Email: Pittayawat.P@chula.ac.th

(Received 4 September 2021; revised 7 August 2023; accepted 19 August 2023;
first published online 17 November 2023)

Abstract

This study investigates interactions among relative syllabic prominence, initial geminates (IGs), and prosodic boundaries in Pattani Malay (PM) against a background of previous analyses claiming that IGs are moraic and trigger a 'stress shift' or the linking of a pitch accent to the initial syllable. We conducted an acoustic study with fourteen PM speakers, producing singleton–IG minimal pairs in naturalistic sentences. Our results show that the presence of IGs is not associated with the hypothesized phonological changes. Instead, it is associated with moderate increases in the duration of initial syllables, the intensity of the initial syllable vowels, and the f0 of the initial and final syllable vowels. On the other hand, the presence of a phrase-final prosodic boundary correlates with more drastic changes: in phrase-final position, final syllables exhibit final lengthening and falling contours of f0 and intensity, while, in the phrase-medial position, no lengthening is observed and f0 contours are rising. Furthermore, the effects of IGs are strongest in the phrase-final position, suggesting interactions between IGs and prosodic boundaries. Taken together, results cast doubts on the claim that IGs are moraic and associated with categorical differences in syllabic prominence profiles in PM and show that IG effects are modulated by prosodic boundaries.

Keywords Pattani Malay; Prominence; Initial geminates; Phrasal boundary

1. Introduction

In the world's languages, consonantal duration can function contrastively to differentiate meaning, for instance, Italian [ˈpala] 'shovel' vs. [ˈpalːa] 'ball'. Such contrasts between short or singleton and long or geminate consonants are subject to various constraints. A well-known constraint is that singleton vs. geminate contrasts are often licensed word-medially but more rarely in word-initial and/or word-final position (Kraehenmann 2011; Topintzi & Davis 2017). Pattani Malay (PM), an Austronesian language spoken in Southern Thailand,

[†]These authors contribute equally to this work and share first authorship.

Table 1. Pattani Malay minimal pairs showing lexical contrast for initial singletons and geminates

Words without IG	Word with IG
[buwɔh] 'fruit'	[bːuwɔh] 'to stand'
[ɟalɛ] 'path, road'	[ɟːalɛ] 'to walk'
[matɔ] 'eye'	[mːatɔ] 'jewelry'
[kɨda] 'shop'	[kːɨda] 'at the shop'

does not conform to this generalization. Instead, the language licenses singleton vs. geminate contrasts for all segments only in word-initial position, as illustrated in Table 1.

Pattani Malay geminates are remarkable not only because they are always initial geminates (IGs) but also because their presence has been claimed to trigger categorical differences in the prominence profiles of words that contain them. Several researchers (Yupho 1989; Hajek & Goedemans 2003; Topintzi 2008) have claimed that PM words without IGs exhibit final stress and words with IGs exhibit initial stress, for instance, [maˈtɔ] 'eye' vs. [ˈmːatɔ] 'jewelry'. The difference between the two categories of words is captured by different phonological representations and rules that trigger a change in the position of stress. Specifically, PM IGs have been analyzed as moraic such that the presence of IGs increases the prosodic weight of initial syllables, which are therefore assigned stress (Hajek & Goedemans 2003; Topintzi 2008).

This phonological analysis seems *prima facie* compatible with results of phonetic studies (Abramson 1987; Abramson 1998; Phuengnoi 2010), which show that the presence of IGs is associated with an increased saliency of initial syllables. However, the narrow scope and limitations of previous phonetic work on the language suggest caution in marshalling phonetic evidence in favor of the phonological analyses outlined above. Notably, phonetic studies of PM were not designed to study prominence, but only the acoustic consequence of IGs.

An outstanding issue is that IGs in PM have only been studied in words produced in isolation or in phrase-final position within a carrier sentence (Abramson 1987; Abramson 1998; Phuengnoi 2010). However, studying IGs and prominence only in isolation or in phrase-final position is problematic because the prominence profiles of words produced in isolation may reflect phrase level – rather than word level – acoustic patterns. Similarly, the presence of phrase-final boundaries may affect the acoustic profiles of words, which are related to phonological prominence. More specifically, final boundaries may affect the relative duration of syllables and induce more drastic f0 and intensity falling contours on final syllables. Thus, phrase-final boundaries can potentially obscure the relative prominence profiles of final and non-final syllables and the effect of IGs on them.

In this paper, we attempt to dissect the contribution of IGs and prosodic boundaries in PM to increase our understanding of syllabic prominence in this understudied Malay variety. We conducted an acoustic study of PM words with and without IGs produced in relatively naturalistic speech and two prosodic positions: phrase-medial and phrase-final.

Based on previous phonetic phonological work on PM, in this paper we pose two research questions. The first is whether the presence of IGs affects the prominence profile of PM words. This is to ascertain the merits of a 'stress shift' account (e.g., Topintzi 2008), which predicts categorical differences in acoustic cues typically associated with stress or pitch accents (Gordon & Roettger 2017). The second question is whether position in the utterance affects the acoustic prominence profile of PM words. We hypothesize that words in

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

the phrase-medial position and at prosodic boundaries show categorial differences with respect to duration, intensity, f0, and spectral tilt. A more detailed overview of the research questions and our hypotheses is presented in Section 3.

2. Literature review

2.1 Language background and claims regarding the interactions between initial geminates and prominence in Pattani Malay

Known colloquially as Yawi or Jawi, PM is one of the few Austronesian languages spoken in Mainland Southeast Asia. According to the 2010 census (National Statistical Office 2012), approximately 1.47 million people speak PM at home. PM forms a dialect continuum with Kelantan Malay and other northeastern peninsular Malay varieties spoken to the south of Thailand, just across the Malaysian border (Collins 1989: 241–244). While Standard Thai is the sole national and official language of Thailand and the only language of instruction in schools, PM is the dominant language in the three border provinces, namely, Pattani, Yala, and Narathiwat, and some districts in the province of Songkhla (Smalley 1994 155–175). Although the presence of Thai in the area has increased, PM remains the preferred language used in the family, and the primary linguistic code for communication among ethnic Malays, especially in rural areas. Additionally, proficiency in PM remains high because children acquire this language before starting school (Poonsub 2016; Premsrirat & Burarungrot 2018: 239; Premsrirat & Burarungrot 2022).

Pattani Malay is well-known in the phonetic and phonological literature as a language with geminates attested only in word-initial position. PM shares this feature with a few other Austronesian languages, such as Leti, Ngada, and Yapese, as well as the Austroasiatic language Nyaheun (Muller 2001; Topintzi & Davis 2017). PM IGs are tied overwhelmingly to disyllabic words because they diachronically originated from the reduction of erstwhile trisyllabic forms or tetrasyllabic reduplicated forms (Paramal 1991).

All possible onset consonants in PM have a geminate counterpart, except for /r/ and /z/ which are found only in recent loan words (Uthai 1993: 91). Table 2 illustrates the consonant inventory of PM. Note that PM does not have phonemic /f/ and /x/. Surface geminates [fː] and [xː] are stylistic variants of /kɨɣ-/ and /pɨɣ/, respectively.

Only one study, Phuengnoi (2010), has been devoted to the acoustics of prominence in PM by comparing syllables within a word and across words with and without IGs. Assuming that Yupho's (1989) description of identifying stressed and unstressed syllables was valid, Phuengnoi investigated the acoustic correlates of the stress by using data from seven male native speakers. The stimuli were monosyllabic, disyllabic, and trisyllabic words without IGs and compared with disyllabic words with IGs. The main findings are as follows. For vowel duration, final syllables in words with and without IGs have a longer vowel duration than initial syllables. Regarding f0, in words with and without IGs, the mean f0 is higher on initial syllable vowels than on final syllable vowels (Figure 1). Moreover, the mean f0 of initial syllable vowels in words with IGs is higher than in words without IGs (Figure 1, left). For intensity, initial syllable vowels in words with and without IGs have higher mean intensity than final syllables. When comparing initial syllables of words with and without IGs, syllables with IGs have significantly higher mean intensities. Crucially, Phuengnoi also found that the f0 contours for both words with and without IGs show falling profiles over the whole word and that final syllables have nearly identical f0 contours (Figure 1, right).

A major finding of Phuengnoi (2010) is that words with and without IGs display the same relative duration and f0 and intensity contours: final syllables are always longer, have lower f0, and lower intensity than initial syllables. The magnitude of the values is different, however, especially for f0 and intensity of the initial syllable when comparing words with

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table 2. Consonant inventory in Pattani Malay (PM) (Uthai 2011)

		Labial		Alveolar		Palatal		Velar		Glottal	
stop	voiceless	p	pː	t	tː	c	cː	k	kː	ʔ	ʔː
	voiceless aspirated	pʰ	pːʰ	tʰ	tːʰ	cʰ	cːʰ	kʰ	kːʰ		
	voiced	b	bː	d	dː	ɟ	ɟː	g	gː		
fricative	voiceless		(fː)	s	sː				(xː)	h	hː
	voiced			z				ɣ	ɣː		
nasal		m	mː	n	nː	ɲ	ɲː	ŋ	ŋː		
lateral				l	lː						
trill				r							
glide		w	wː			j	jː				

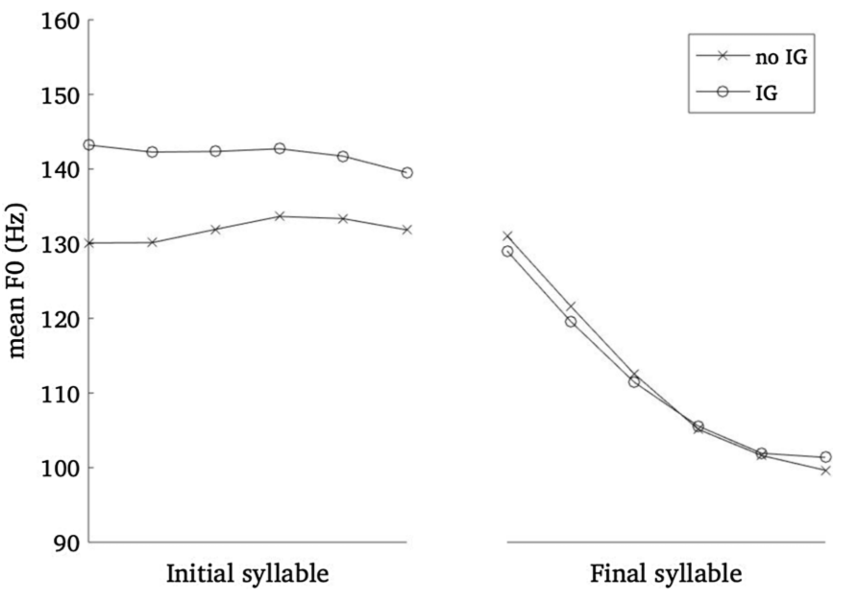

Figure 1. f0 contour of disyllabic words with (CːV.CV) and without initial geminates (CV.CV) (Phuengnoi 2010).

singleton and IG onsets (Figure 1, left). Phuengnoi's results also decidedly speak against the idea of stress shift as the f0, intensity, and durational patterns are invariant across words with and without IG onsets.

Unfortunately, one major caveat with Phuengnoi's study is that it is limited to words recorded in isolation. Thus, the data presented only represent words immediately preceding an utterance boundary. Similar caveats hold for previous investigations of IGs in PM. The data presented in Abramson's (1987, 1998) studies were elicited in isolation and in a carrier sentence, but the analyses were performed without considering or discussing potential differences due to phrasal positions. Accordingly, what is unclear is whether the reported effects on syllabic prominence are due to IGs, phrasal boundaries, or a potential

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

interaction between the two. Because of the difficulties in establishing a clear pattern of IG behavior and potential interactions with prominence, a study that simultaneously manipulates IGs and prosodic boundaries may help us dissect their relative contribution to syllabic prominence in PM.

2.2 Syllabic prominence in Malay varieties

The role that relative syllabic prominence plays in the sound systems of Malay varieties, especially those spoken in Indonesia, is still a matter of controversy among researchers. Maskikit-Essed and Gussenhoven (2016) identified three main views on word-level prominence in Malay varieties. The first view assumes that the position of stress is fixed either on the penultimate or the ultimate syllable, additionally, syllables with [ə] are unstressed (e.g., Cohn 1989; McDonnell 2016). This approach is sometimes known as the "traditional view." A second view also assumes that Malay varieties display word-level prominence, but the assignment of prominence is conditioned by the position of the word in the utterance, e.g., words in phrase-medial position show penultimate stress, and words in phrase-final position show final stress (e.g., Halim 1974). Finally, the third view claims that these languages do not have word-level stress, and the "prominence" described as stress in other studies is phrase-level prominence (e.g., Mohd Don et al. 2008; van Heuven et al. 2008). While these conflicting views reflect actual linguistic heterogeneity, they may in part stem from lack of in-depth acoustic investigation on some of the reported varieties (cf. Kaland 2021 for a similar conclusion).

Despite disagreements among phonological analyses, many Malay varieties show remarkably similar acoustic behaviors when phrasal prosody is considered. Reports on the acoustic behavior of several Malay varieties show that durational increase and f0 movements that could be symptomatic of prominence are not concomitant. In most of the Malay varieties that have been studied acoustically, final syllables invariably display longer durations, and f0 contours vary by the position of words in the phrase and/or by discourse conditions (e.g., declarative vs. interrogative clauses). There are varieties that show falling f0 contours when words appear in phrase-final position, including words in isolation, and rising f0 contours when words appear in phrase-medial position, namely, Besemah (McDonnell 2016), Malaysian Malay (Mohd Don et al. 2008), and Ambonese Malay, which also display rising contours on final words in interrogative sentences (Maskikit-Essed & Gussenhoven 2016). Other varieties, for example, Indonesian spoken by speakers from southern Sumatra (Halim 1974) and Betawi Malay (van Heuven et al. 2008), display rising contours in phrase-final position and falling contours in phrase-medial position. However, exceptions to this common pattern have also been reported in the literature. Indonesian spoken by Javanese speakers, as reported by Goedemans and van Zanten (2007), shows consistent f0 contour patterns: rising contours on phrase-medial words, elicited out of focus, and falling contours on phrase-final word, elicited under focus. In contrast, there is no clear duration pattern: neither penultimate nor ultimate syllables are reported to be consistently longer than the other syllables. Indonesian spoken by Toba Batak speakers is another interesting case, where f0 and duration are used together to increase prominence on a single syllable, such as in a prototypical stress language. This language also does not show the different contours depending on the position in a phrase.

Another variety that stands out is Papuan Malay, reported to have penultimate stress, except for words with [ɛ] in penultimate syllables, which have ultimate stress instead (Kluge 2017). An acoustic study of words in phrase-medial position by Kaland (2019) shows that acoustic correlates of stress in Papuan Malay are the duration of segments, the timing of f0 movement (rising/falling contours), vowel formant displacement, and spectral tilt (H1−A2, H1−A3). Other parameters, such as relative pitch height, do not correlate with stress. Further work on the language has shown that f0 contours seem to correlate with phrasal-level prosody: rising contours are observed in phrase-medial position, while falling contours are observed in phrase-final position (Kaland & Baumann 2020). This behavior of f0 follows the general trend of Malay varieties and suggests that in these languages, f0 may be associated with phrasal prosody, while other cues, such as duration, spectral tilt, etc., may be associated with word-level prosody (Gordon 2014; Gordon & Roettger 2017; Kaland 2021).

As for PM, previous acoustic studies of PM (Abramson 1987, 1998; Phuengnoi 2010) seem to suggest that the language shows a dissociation of duration and other parameters. More specifically, the duration of final syllables is always higher than other syllables; but intensity and f0 are found to be higher on the initial syllables, regardless of the presence of IGs (Phuengnoi 2010) or found to be higher on initial syllables when the IGs are present (Abramson 1987, 1998). However, whether the behaviors are due to phrasal effects remains unclear because the words studied were recorded in isolation or at the end of a carrier sentence. However, to understand how relative syllabic prominence interacts with IGs and phrasal boundary in this understudied variety of Malay, all cues that have been reported as relevant for prominence in Malay varieties must be examined.

3. Research questions, hypotheses, and predictions

Based on the literature review, this paper aims to address two primary research questions concerning the prominence profiles of words in PM.

(i) Does the presence of IGs affect the prominence profile of PM words?

(ii) Does position in the utterance affect the prominence profile of PM words?

For our first question, we have two logical alternatives: either IGs affect the prominence profiles of PM words or they do not. If we follow previous phonological descriptions and analyses, it is reasonable to expect categorically different profiles in words with and without IGs. In disyllabic forms, prominence profiles of words with and without IGs are then expected to be mirror images of each other. Words with IGs are expected to have initial prominence, while words without IGs are expected to have final prominence.

By examining acoustic dimensions that are relevant for stress or pitch accents – such as duration, intensity, f0, vowel quality, and spectral tilt (Gordon & Roettger 2017), words containing IGs would be expected to have more extreme values, compatible with prominence, on initial syllables than on final syllables. These acoustic cues include longer duration, higher intensity, higher f0, more extreme vowel quality, and higher spectral tilt. On the other hand, words not containing IGs would be expected to have values more compatible with prominence on final rather than initial syllables.

Alternatively, it is also possible that words with IGs do not display different prominence profiles. PM disyllabic words may have fixed prominence on the initial syllable, or on the final syllable, or neither of the two syllables may be more prominent than the other. If prominence is fixed initially or finally, we expect initial or final syllables respectively to display more extreme acoustic values compatible with prominence no matter whether they contain IGs or not. Finally, if neither of the two syllables is more prominent than the other, we expect to observe no clear patterns of greater relative prominence between the two syllables. Figure 2 illustrates the predicted acoustic profiles under the hypothesis that IGs have a categorical effect and the hypothesis that PM has a fixed (final) prominence.

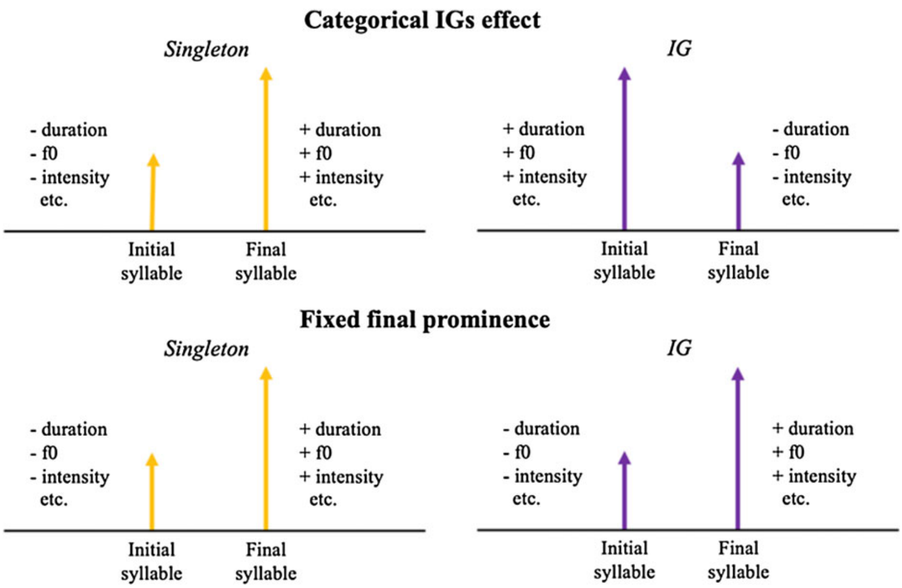

Figure 2. (Colour online) Predicted acoustic profiles based on stress shift hypothesis (top) and fixed (final) prominence hypothesis (bottom).

For our second research question, we similarly have two alternative scenarios: either the presence of a phrasal boundary affects the realization of the prominence profiles of syllables, or it does not. If phrasal boundaries categorically influence prominence profiles, we expect final syllables to have different acoustic properties in phrase-medial and phrase-final position. Final syllables may be longer in phrase-final than in phrase-medial position because of phrase-final lengthening (Byrd & Saltzman 2003; Edwards et al. 1991; Turk & Shattuck-Hufnagel 2007; Wightman et al. 1992). Similarly, f0 may fall more drastically, possibly together with intensity, in the vicinity of a phrasal boundary, as has been observed in other Malay varieties (e.g., Mohd Don et al. 2008; Maskikit-Essed & Gussenhoven 2016). The hypothesis that PM would show falling contours instead of rising contours is according to Phuengnoi's (2010) report of words in isolation.

Moreover, phrasal position may affect the differences between final and initial syllables. For example, it is possible that the durational difference between final syllables and initial syllables will be more pronounced in phrase-final position again due to boundary-adjacent lengthening. Similarly, f0 and intensity contours over the word may be flat or rising in phrase-medial position but falling in phrase-final position. Interestingly, the predicted phrasal boundary effects lead to a dissociation of the acoustic correlates that are typically manipulated in tandem by speakers producing stress or pitch accents. The syllables adjacent to a phrase-final boundary have longer durations, a property typical of prominent syllables, but also falling and generally lower f0 and intensity, a property typically associated with non-prominent syllables.

A logical alternative would be that prosodic boundaries do not systematically affect the relative prominence of syllables in PM words. If this is the case, we do not expect to observe differences in the acoustic realization of final and initial syllables in phrase-medial and phrase-final position. Studying IGs and phrasal boundaries together also allows us to investigate their potential interactions.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

4. Methodology

4.1 Participants

The participants were fourteen speakers of PM (six males, eight females), aged from twenty to sixty-one years ($\mu = 33$, $\sigma = 15$). All speakers were born and raised in the three southernmost provinces of Thailand, namely, Pattani, Yala, and Narathiwat; they reported native proficiency in PM and native-like fluency in Thai. These speakers are sequential bilinguals because the ages at which they learned Thai are the same as those of kindergarten and elementary school students. Speakers did not disclose any speech or hearing impairment.

4.2 Materials and experimental task

Disyllabic words were used as IGs are only attested in monosyllabic and disyllabic forms (Paramal 1991); however, the former are uninformative regarding prominence profiles. Thirteen disyllabic minimal pairs differing only in singleton *vs.* geminate onsets were selected from the literature (Abramson 1987, 1998; Hamzah et al. 2011, 2014); Table 3 presents the full list. A fourteenth minimal pair [*pitu*] 'door' [*pːitu*] 'at the door' was also collected, but we did not analyze it because participants produced the geminate form in a non-assimilated prepositional phrase form, namely, [*di pitu*].

Note that the stimuli were not balanced for onset manners. This was not possible as we wanted to ensure that all participants were familiar with the target words. However, we do not expect stimuli with plosive and sonorant onsets to behave differently, as in Kelantan Malay (Hamzah 2013), which forms dialect continuum with PM. Even though voiceless stop IGs show a stronger effect on vowel intensity and f0, voiced stop and sonorant IGs also show a significant effect on intensity and f0 with the same direction of effect.

Although Arabic-based, Roman-based, and Thai-based scripts have been designed for PM, its speakers are usually illiterate in the language (Paramal 1991: 40; Smalley 1994). Accordingly, it is not possible to rely on written stimuli to elicit the target words. To obviate this problem, participants were familiarized with pairs of PM sentences containing the target word and their Thai translation to avoid ambiguity of the stimuli and mistakes in translation. In the experiment, participants were cued using the Thai translation of the target sentences uttered by an experimenter, after which participants produced the corresponding PM version containing the target words. Whenever participants' production contained a mistake, such as disfluencies, pauses, or speech errors, participants were asked to repeat the trial. Although this task may resemble a translation task or a repetition task, we consider it ecologically valid for the following reasons. First, because participants are familiarized with translations of each sentence before the experiment, they are not translating online word by word. Hence the Thai sentence is simply a cue for a PM sentence. Accordingly, it is not very likely that participants would be attending to finer details of the Thai production of the utterance.

We opted to elicit target words by orally presenting them in natural-sounding PM and Thai sentences (Appendix A), our main consideration being that a more realistic picture of prominence requires the production of PM IGs in a more naturalistic context in which IGs are less likely to be hyperarticulated. The production of PM IGs in less naturalistic contexts, for example, in isolation or a carrier sentence, has been investigated; the results demonstrate that segmental and phrasal effects are difficult to separate (Section 1.2). This problem is frequently observed in studies on stress and prominence (Gordon & Roettger 2017). On the basis of this background and claims in the literature on Malay varieties (Kaland 2019), we subscribe to the idea that naturalistic speech yields more representative samples than read speech for the study of word-level prominence.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table 3. The thirteen minimal pairs of disyllabic forms that differed uniquely for the singleton or initial geminate (IG) onsets of the initial syllable

Singleton (CVCV)	Gloss	IG(C:VCV)	Gloss
[pagi]	'morning'	[p:agi]	'early morning'
[paka]	'to use/wear'	[p:aka]	'usable'
[tanɔh]	'land'	[t:anɔh]	'outside'
[dapo]	'kitchen'	[d:apo]	'at the kitchen'
[katoʔ]	'hammer'	[k:atoʔ]	'frog'
[kabo]	'Java kapok'	[k:abo]	'beetle'
[gaɟɨ]	'wage'	[g:aɟɨ]	'saw'
[ɟalɛ]	'path'	[ɟ:alɛ]	'to walk'
[misa]	'mustache'	[m:isa]	'to grow a mustache'
[labɔ]	'profit'	[l:abɔ]	'spider'
[bulɛ]	'moon'	[b:ulɛ]	'month'
[buŋɔ]	'flower'	[b:uŋɔ]	'to bloom'
[ɟ:uɣi]	'to steal'	[ɟ:uɣi]	'thief'

The effects of IGs, prosodic boundaries, and their interaction were tested: target words were elicited in both phrase-medial and phrase-final positions. Each sentence was repeated three times. In total, twenty-six tokens (thirteen unique minimal pairs) × two phrasal conditions (medial vs. final) × three repetitions × fourteen speakers = 2,184 tokens were collected; 212 tokens were excluded because of strong background noise in the sound files or equipment failures. Thus, 1,972 tokens were analyzed: 932 contained IGs and 1,040 contained singletons.

4.3 Data collection and processing

Audio data were collected at 44.1 kHz in Praat (Boersma & Weenink 2020) by using a Rode NT-USB, a cardioid condenser microphone. We use a cardioid microphone placed on a table near participants (like other work on Malay prominence, Kaland 2019) to have a more naturalistic setting. This choice may have led to more variation in intensity measurements and, thus, to less accurate estimates of intensity effects. Future work could attempt to produce a PM corpus where microphone distance is tightly controlled to ensure a more accurate picture of the effects of IG and prosodic boundaries on intensity.

All recordings were made in quiet rooms at the Prince of Songkla University, Pattani Campus, Pattani, Thailand. We first identified target words and labeled them using Praat TextGrids; subsequently, the portion of the audio signal representing the target words was extracted using MATLAB (MATLAB 2021). Segmental boundaries were obtained in Praat TextGrids by forced alignment with a custom-built model trained using the Montreal Forced Aligner on our dataset (McAuliffe et al. 2017). The TextGrids were inspected and manually corrected when necessary. Corrected TextGrids containing segmental boundaries and audio signals of each word were read back in MATLAB for analysis.

The variables analyzed were syllable duration, vowel f0, vowel intensity, vowel formants, and spectral tilt (H1−A2, H1−A3). For the duration, we first analyzed the (Ia) raw duration of singleton and geminate consonants and the (Ib) durational ratio of the consonants to the entire word ($\frac{c}{w}$) to confirm that singleton/IG onsets are distinguishable by duration. We then analyzed (II) the duration ratio of the initial syllable (σ_i) to the entire word ($\frac{\sigma_i}{w}$) across IG *vs.* singleton conditions, as well as (III) the ratio of the final syllable (σ_f) to the entire word ($\frac{\sigma_f}{w}$) in the IG *vs.* singleton condition. Duration ratios were used because target sentences differ in numbers of syllables, and we considered duration ratios of syllables to yield a more stable measurement across sentences with different numbers of syllables. Furthermore, (IV) we analyzed the difference in duration ratios between $\frac{\sigma_f}{w} - \frac{\sigma_i}{w}$ in the singleton and IG conditions. For the duration ratio, no outliers were excluded.

f0 values were calculated by using the MATLAB *pitch()* function, namely, the normalized correlation function algorithm (Atal 1972) with a 30 ms window length and 29 ms overlap. F0 values were normalized by converting Hz to z-scores, separately for each participant, to remove anatomically driven differences in f0 due to the participant's sex and age. Five trials of the vowels in final syllables were excluded because the f0 vectors contained less than two data points per vowel. F0 contours were smoothed using smoothing splines to remove microprosodic effects due to neighboring segments and potential pitch tracking artifacts. In particular, cubic spline interpolants were fit to the raw f0 data and their time points to obtain a smoother f0 contour that is amenable to analysis with polynomial growth curve functions. Finally, f0 contours were time-warped to a fixed length, a necessary step for the growth curve analyses.

Sound Pressure Level (SPL) normalized intensity was calculated by transforming the root mean squared amplitude of the signal to dB and normalizing it to human auditory threshold using the formula $20 \times log_{10}\frac{I}{I0}$, where I is the amplitude of the signal, and $I0$ represents the normalizing term for the auditory threshold of a 1000 Hz sine wave, equal to 2×10^{-5} (Huang et al. 2001: 22). Intensity values were calculated with a 30 ms window length and 29 ms overlap to match the f0 windowing. Next, intensity values in dB were converted to the z-score separately by participant to remove differences among participants due to recording conditions. No outliers were excluded except for five trials of the vowels in final syllables in which the intensity vectors contained fewer than two data points. Finally, intensity contours were also time-warped to obtain a fixed length.

We used a linear predictive coding algorithm in MATLAB (Yao et al. 2010) to extract vowels F1 and F2. The audio signals were first downsampled to 8 kHz. LPC order was adjusted per the speaker's sex: twelve coefficients for male speakers, and ten coefficients for female speakers. Minimum and maximum F1 and F2 values were set for each vowel, as required by the algorithm and to prevent erroneous tracking during the Viterbi step of formant tracking, on the basis of Iemwanthong's (2008) report on the acoustics of PM vowels. We first extracted the acoustic measurements with fixed window length of 30 ms and 15 ms time step. Values at the midpoint of the trajectories were selected because all the target vowels in this study are monophthongs. Tokens with a duration shorter than 30 ms and those whose F1 and F2 were outside the expected frequency range were excluded. These amounted to twenty-three tokens for F1 of the first vowels, nineteen tokens for F2 of the first vowels, ninety-two tokens for F1 of the second vowels, and thirty-two tokens for F2 of the second vowels.

For spectral tilt measures, we used H1−A2 and H1−A3 because these were reported to be significant acoustic correlates of prominence in Papuan Malay (Kaland 2019), even though the cue is not significant in Ambonese Malay (Maskikit-Essed & Gussenhoven 2016). First, we calculated FFT spectra, using the MATLAB *fft()* function (Frigo & Johnson 1998). We used Hamming windows with 1,024 samples, or approximately 25 ms, extracted from the middle of the vowels. The amplitudes were then transformed into dB and normalized

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

to human auditory threshold using the formula for intensity. The first harmonics, or H1, were extracted from the first peak of the FFT spectrum. A2 was extracted from the highest peak of the FFT spectrum closest to the F2 and A3 extracted from the highest peak of the FFT spectrum closest to the F3. The F2 and F3 values were extracted using the same method as that used to extract formant frequency in the prior paragraph. We did not correct the H1, A2, and A3 values, because Kaland (2019) reported for another Malay variety that uncorrected values are better acoustic correlates for stress than corrected values.

4.4 Data analysis

Effects of IGs and phrasal position on duration, F1, F2, H1-A2, H1-A3, the mean intensity difference between the final and the initial syllables, and the mean f0 difference between the final and the initial syllables were tested by hierarchically building nested linear mixed-effect regression models. We started with models that contained random intercepts only. The random intercepts for the models with duration include speaker and onset, while the random intercepts for the other models include speaker, onset, and vowel. We then tested whether adding fixed effects for the presence of IGs, for phrasal position, and for the interaction between these two fixed effects improved model fit. Each time a fixed effect was added to the model, random slopes were included in the model. Contrast was coded such that singleton and phrase-medial positions represent the baseline values for the presence of IGs and for phrasal position, respectively. The random effects for models with duration as the dependent variable include speaker and manner/place of the syllable onset segments. On the other hand, the random effects for models with formant frequencies or spectral tilts as a dependent variable include speaker and vowel quality. Because we did not control for vowels in initial and final syllables, formant analysis was limited to a comparison of singletons/IGs and phrase-medial/phrase-final positions, i.e., no comparison between syllables was conducted. Linear mixed-effect models were compared using MATLAB *compare()* function to perform likelihood ratio tests. The test statistics (χ^2) and the p-values reported are the result of the likelihood ratio tests.

F0 and intensity contours were analyzed using third-order orthogonal polynomial growth curve analysis. Effects of the presence of IGs and phrasal position were tested by hierarchically building nested models (Mirman 2014). We started with the models containing only a random effect for subject and word but neutralized for the singleton/geminate difference to avoid collinearity with the fixed effect for IG presence. We then tested whether adding fixed effects for the presence of IGs, for phrasal position, and for the interaction between these two fixed effects improved model fit. If the fixed effects improved the model fit, each time, we added the interactions of the fixed effects with orthogonal linear, quadratic, and cubic time (Mirman 2014). The fixed effect indicates differences in mean across conditions; the interaction with linear time indicates differences in slope, and the interaction with quadratic and cubic time indicates differences in shape and curvature. The random effects included in these models are random intercepts for subject and word. Growth curve models were compared using the *anova()* function in R which performs a likelihood ratio test. The test statistics (χ^2) and the p-values reported are the result of the likelihood ratio tests between nested models. When the best fitting models were found to have an interaction term between IGs and utterance position, the test statistics reported were obtained from a comparison with a model that has fixed effects for IG and utterance position. On the other hand, when the best fitting models were found to have terms for both IGs and utterance position, but no interaction term, the test statistics come from a comparison with a model that has fixed effects for IG or utterance position, for which we report only the lower χ^2. Finally, when neither IGs nor utterance position were found to have significant effects, the test statistics come from a comparison with a null model containing no fixed effects, but only random effects. Effects are reported as significant based on the approximate *t*-statistic returned by mixed effect models, based on the ratio of estimated coefficients to their standard error and *n-p* degrees of freedom where *n* is the number of observations and *p* the number of parameters (Gałecki & Burzykowski 2013). The models fitted for each dependent variable are reported in Appendix B.

5 Results

5.1 Duration

Before discussing the effects of different onsets, we first studied whether IGs and singletons onsets are reliably distinguished in duration. We found that the raw duration of IGs is longer than that of singletons ($\chi^2_{(1)} = 6.07$, $p = .01$), with an estimated effect size of 17 ms (95% CI [6, 28] ms). We also found that IGs are longer than singletons in the duration ratio of the onset to the entire word ($\frac{C}{W}$) ($\chi^2_{(1)} = 7.44$, $p = .006$), with an estimated effect size of .03 (95% CI [.012, .048]). The differences between singletons and IGs in both raw and normalized duration suggest two distinct categories.

At the syllable level, we found that both phrasal position and the presence of IG onsets have a significant effect on the duration ratio of the initial syllable to the word ($\frac{\sigma_i}{W}$), but their interaction does not ($\chi^2_{(1)} = 5.10$, $p = .023$). In phrase-final position, initial syllables have a lower duration ratio to the word in comparison to final syllables, with an estimated effect size of -0.1 (95% CI [-0.13, -0.07]). The presence of IGs makes the duration ratio of initial syllables to the word higher than the duration ratio of final syllables to the word by approximately 0.015 (95% CI [0.004, 0.026]; Figure 3).

Similarly, we found that both phrasal position and the presence of IG onsets have a significant effect on the duration ratio of the final syllable to the word, but their interaction

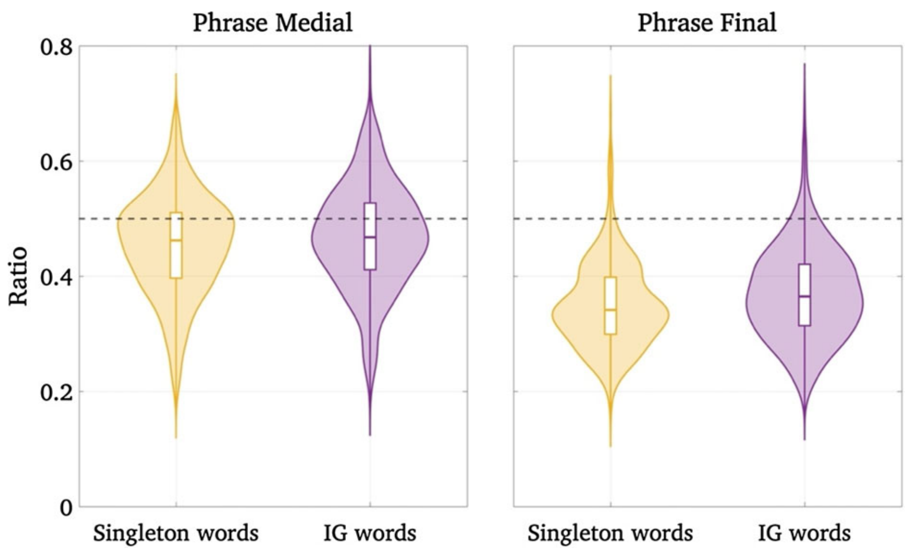

Figure 3. (Colour online) Left: duration ratio of initial syllables to the entire word phrase-medially. Right: duration ratio of initial syllables to the entire word phrase-finally. Dashed line marks 0.5 of syllable duration.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

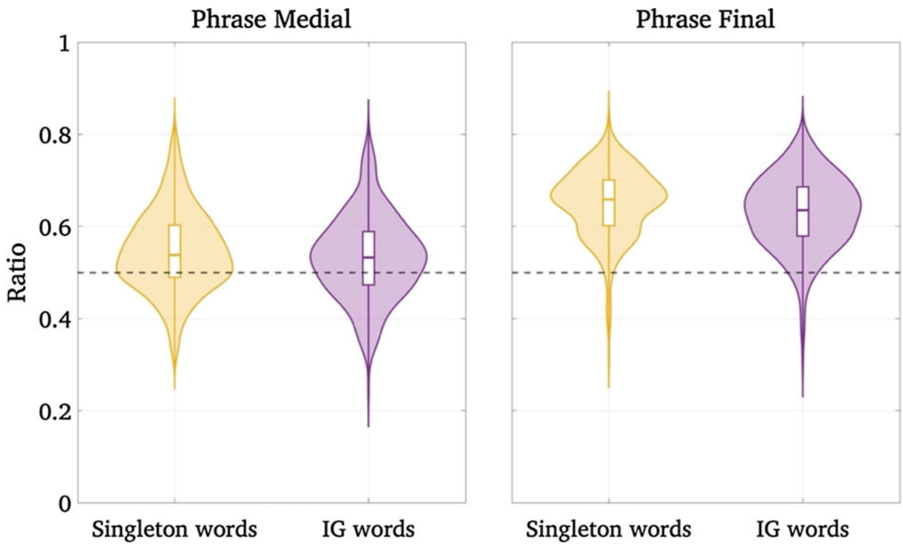

Figure 4. (Colour online) Left: duration ratio of the final syllables to the entire word phrase-medially. Right: duration ratio of the final syllables to the entire word phrase-finally.

does not ($\chi^2_{(1)} = 5.10$, $p = .023$). In phrase-final position, final syllables have a higher duration ratio to the word in comparison to initial syllables, with an estimated effect size of 0.1 (95% CI [0.07, 0.13]). The presence of IGs makes the duration ratio of the final syllable to the word lower than the duration ratio of initial syllables to the word by approximately −0.015 (95% CI [−0.026, −0.004]; Figure 4).

Finally, we found that both phrasal position and the presence of IG onsets influence the difference in the duration ratio between the final and initial syllable, but their interaction does not ($\chi^2_{(1)} = 5.10$, $p = .023$). In phrase-final position, the difference in the duration ratio of the final and initial syllable increases in comparison to the duration ratio in phrase-medial position, with an estimated effect size of 0.2 (95% CI [0.15, 0.26]). The presence of IGs makes the difference in duration ratios smaller in comparison to the difference in words with singleton onsets by approximately −0.03 (95% CI [−0.05, −0.008]).

5.2 Intensity

Our main findings for intensity show that IGs do not have strong effect, besides a small effect on curvature. Position has a strong effect on both vowels: intensity contours are lower in utterance-final position, and they also have steeper fall over words. We also observe an interaction: intensity on initial syllables is higher after IGs than after singleton, but only in final position. This finding showcases an interaction between IGs and phrasal boundaries that results in steeper intensity falls over words with IGs appearing in phrase-final position.

For intensity of the initial syllable, a stepwise likelihood ratio test suggests that the interaction of the presence of IGs and position with linear time, quadratic time, and cubic time are significant ($\chi^2_{(4)} = 833.23$, p <.001).

No significant effect of the presence of IGs on the mean intensity of the initial syllable vowels was observed. By contrast, we found a significant effect for position, with an estimated effect size of −0.26 z-scores. This finding indicates that vowels in phrase-final words

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

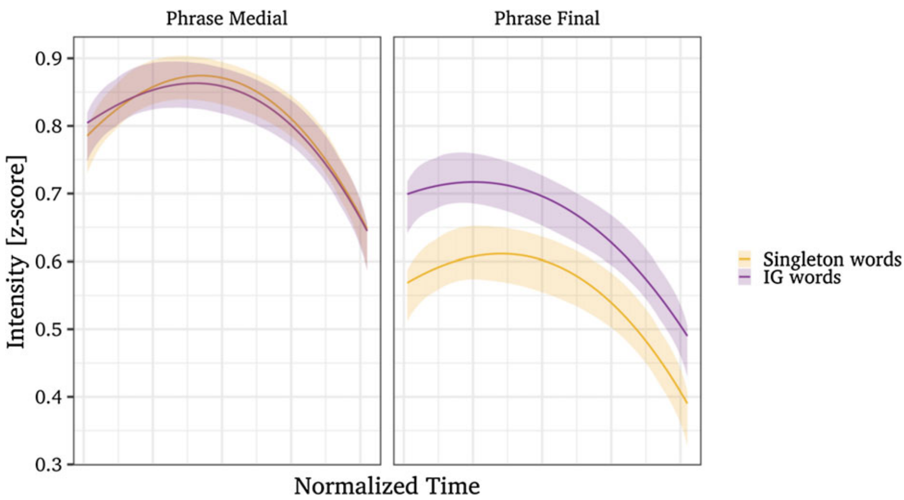

Figure 5. (Colour online) Left: model fit of the intensity contour of the *initial* syllable vowels in phrase-medial position; shaded area represents two standard errors above and below the empirical mean. Right: model fit of the intensity contour of the *initial* syllable vowels in phrase-final position.

have lower intensity than those in phrase-medial words, by −1.44 dB to −2.09 dB depending on the intensity range of the speaker. Similarly, the interaction of the presence of IGs and position has a significant effect, with an estimated effect size of 0.11 z-scores. This finding indicates that the vowels after IGs have an additional increase in mean intensity only in utterance-final position, estimated to be 0.61 dB to 0.89 dB depending on the intensity range of the speaker.

We only observe a significant effect of the interaction of linear time and position, with an estimated effect size of −0.10 z-scores (−0.55 to −0.81 dB). However, no effect of the interaction of linear time and the presence of IGs nor the interactions among linear time, presence of IGs, *and* position were observed. These findings indicate that position in the utterance influences the intensity contours' slope but that the presence of IGs and their interaction with position does not. The effect of the interaction of quadratic time and the presence of IGs is significant. The effect of the interaction of quadratic time and position is also significant. However, no effect of the interaction among quadratic time, presence of IGs, *and* position was observed. These findings indicate that the presence of IGs and position affect the curvature of the intensity contour but that their interaction does not. Finally, none of the interaction with cubic time is significant. Figure 5 presents the model fit to the data.

For intensity of the final syllable, a stepwise likelihood ratio test suggests that the interaction of the presence of IGs and position with linear time, quadratic time, and cubic time are significant ($\chi^2_{(4)} = 280.84$, $p < .001$).

The effect of the presence of IGs on the mean intensity of the final syllable vowels is significant, with an estimated effect size of 0.04 z-scores. This finding indicates that the vowels in the final syllables of words with IGs have higher mean intensity than those of words with singleton onsets; the estimated effect size is 0.22 dB to 0.32 dB, depending on the speakers' range. The effect of position is significant, with an estimated effect size of approximately −0.60 z-scores. This finding indicates that the vowels in the final syllables of phrase-final words have lower mean intensity than those of phrase-medial words by approximately −3.32 dB to −4.83 dB. The effect of the interaction of the presence of IGs

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

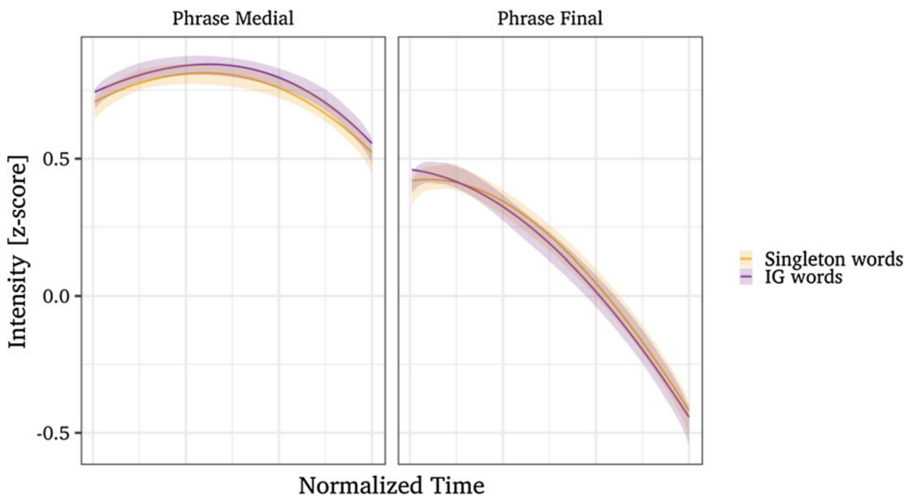

Figure 6. (Colour online) Left: model fit of the intensity contour of the *final* syllable vowels in phrase-medial position. Right: model fit of the intensity contour of the *final* syllable vowels in phrase-final position.

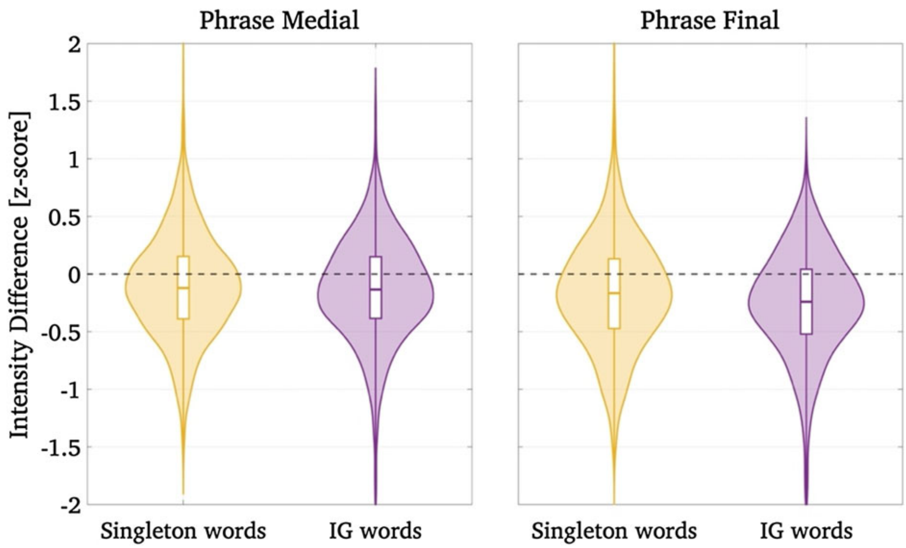

Figure 7. (Colour online) Left: intensity difference of the final minus initial syllable phrase-medially. Right: intensity difference of the final minus initial syllable phrase-finally.

and position is also significant, with an estimated effect size of −0.05 z-scores. This finding indicates that the vowels after IGs have an additional decrease in mean intensity in the final position of an estimated −0.28 dB to −0.40 dB.

No significant effect was observed for the interaction of linear time and the presence of IGs, but we found a significant effect for the interaction of linear time and position, with an effect size of approximately −2.44 z-scores (−13.53 to −19.74 dB). Similarly, the effect of the interaction among linear time, presence of IGs, and position is significant, with an effect size of approximately −0.21 z-scores (−1.16 to −1.69 dB). These findings indicate that position and the interaction of the presence of IGs and position affect intensity contours' slope,

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table 4. Summary of statistical analyses of intensity (significance and effect size)

	Initial geminates vs. singleton				$Vowel_1$ vs. $Vowel_2$	
	$Vowel_1$		$Vowel_2$		$Vowel_2 - Vowel_1$	
	Sig.	Est.	Sig.	Est.	Sig.	Est.
Geminate	n.s.		***	0.04	n.s.	
Linear × Geminate	n.s.		n.s.			
Quadratic × Geminate	*	0.06	n.s.			
Cubic × Geminate	n.s.		n.s.			
Position	***	−0.26	***	−0.60	n.s.	
Linear × Position	***	−0.10	***	−2.44		
Quadratic × Position	***	0.09	***	−0.10		
Cubic × Position	n.s.		**	0.08		
Geminate × Position	***	0.11	***	−0.05	***	−0.12
Linear × Geminate × Position	n.s.		***	−0.21		
Quadratic × Geminate × Position	n.s.		**	0.13		
Cubic × Geminate × Position	n.s.		n.s.			

***p < .001, ** 0.001 < p < 0.01, * 0.01 < p < 0.05, n.s. p > 0.05

but the presence of IGs does not. Similarly, the interaction of quadratic time and the presence of IGs is not significant. The effect of the interaction of quadratic time and position is significant. The interaction among quadratic time, presence of IGs, and position is also significant. No effect was observed for the interaction between cubic time with the presence of IGs, and the interaction among cubic time, presence of IGs, and position. However, the effect of the interaction of cubic time and position is significant. Figure 6 illustrates the model fit.

Finally, the interaction between the presence of IG onsets and phrasal position influences the difference in intensity of the vowels in the final and initial syllables ($\chi^2_{(1)} = 11.85$, $p < .001$). The presence of IGs in phrase-final position corresponds with a more negative difference in intensity between the final and initial syllables, with an estimated effect size of −0.12 z-scores (95% CI [−0.19, −0.05]); this finding corresponds to a range of −0.66 dB to −0.97 dB (Figure 7). Note that even though the best model includes terms for IGs, position, and their interaction, we only observe a significant effect for the interaction term.

Table 4 shows the summary of statistical analyses of intensity.

5.3 Fundamental frequency

Our findings show that words with IGs have slightly higher f0 on both syllables, but the effect is small. Position has a strong effect on f0: f0 contours are rising phrase-medially but falling phrase-finally. As for the interaction between position and IGs, words with IGs

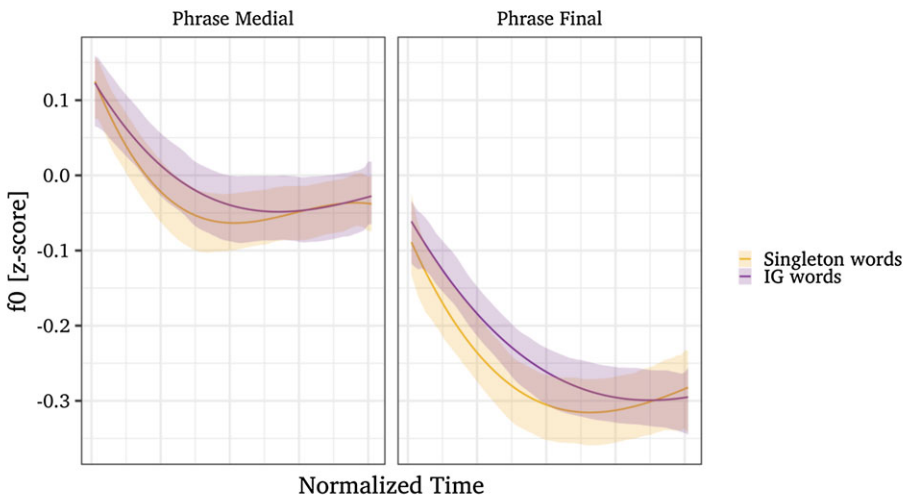

Figure 8. (Colour online) Left: model fit of the f0 contour of the *initial* syllable vowels in phrase-medial position. Right: model fit of the f0 contour of the *initial* syllable vowels in phrase-final position.

in phrase-final position have a less steep fall than predicted by the addition of individual effects. The outcome is that f0 fall is comparable across words with IGs and singletons.

For f0 of the initial syllable, the stepwise likelihood ratio test suggests the interaction between the presence of IGs and position with linear time, quadratic time, and cubic time are significant ($\chi^2_{(4)} = 12.80$, $p = .012$).

For vowels of initial syllables, the effect of the presence of IGs, the position in the phrase, and the interaction of the presence of IGs and position on mean f0 are significant. The effect size of the presence of IGs is approximately 0.01 z-scores. This finding indicates that the vowels following IGs have a higher mean f0 than those following singletons, by 0.23 to 0.4 Hz, depending on the speaker's f0 range. The effect size of the position is approximately −0.23 z-scores. This finding indicates that the vowels in phrase-final position have a lower mean f0 than those in phrase-medial position, by −5.17 to −9.2 Hz, depending on the speaker's f0 range. The effect size of the interaction between the presence of IGs and position is approximately 0.01 z-scores. This finding indicates that vowels after IGs have an additional increase of mean f0 in phrase-final position, estimated to be from 0.23 to 0.40 Hz.

The effect of the interaction between linear time and the presence of IGs is also significant, with an estimated effect size of approximately −0.08 z-scores (−1.8 to −3.2 Hz), and that between linear time and phrasal position is significant, with an estimated effect size of approximately −0.17 z-scores (−3.85 to −6.81 Hz). We also observed the interaction among linear time, presence of IGs, and position, with an estimated effect size of approximately −0.07 z-scores (−1.58 to −2.8 Hz). These findings indicate that the presence of IGs and position and their interaction influence the f0 slope. We observed the interaction between quadratic time with the presence of IGs, but there was no effect of the phrasal position, or their interaction. The effect of the interaction between cubic time and the presence of IGs is significant. Similarly, the interaction between cubic time and phrasal position is significant. No effect was observed for the interaction among cubic time, presence of IGs, and position. Figure 8 illustrates the model fit.

For f0 of the final syllable, the stepwise likelihood ratio test suggests that the interaction of the presence of IGs and position with linear time, quadratic time, and cubic time is significant ($\chi^2_{(4)} = 455.28$, $p < .001$).

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

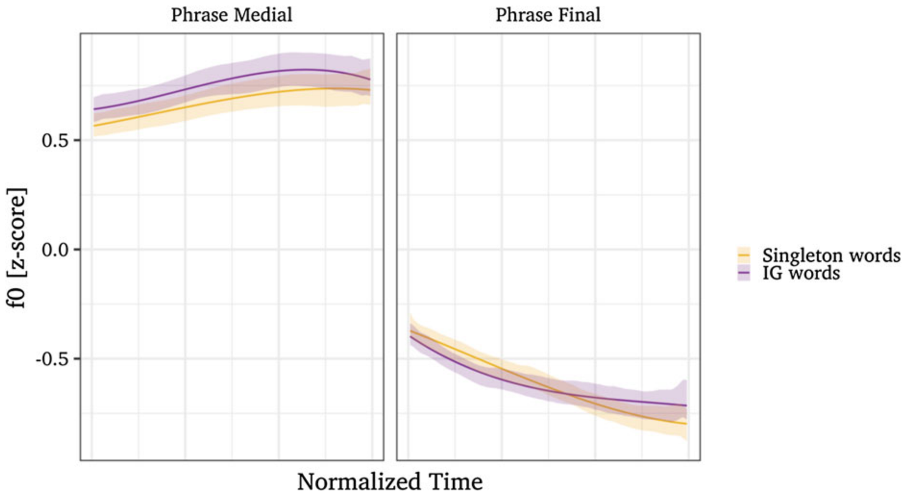

Figure 9. (Colour online) Left: model fit of the f0 contour of the *final* syllable vowels in phrase-medial position. Right: model fit of the f0 contour of the *final* syllable vowels in phrase-final position.

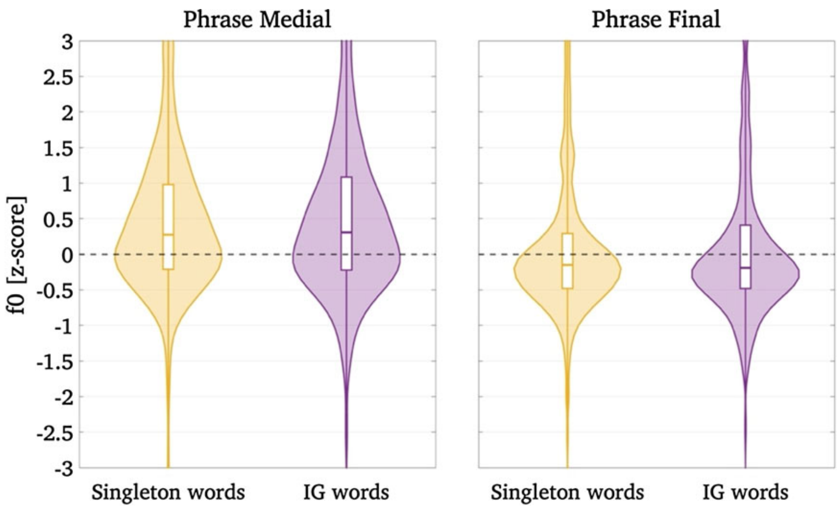

Figure 10. (Colour online) Left: f0 difference of final minus initial syllable phrase-medially. Right: f0 difference of the final syllable minus the initial syllable phrase-finally.

For vowels in final syllables, a significant effect is observed for the presence of IGs, with an estimated effect size of approximately 0.09 z-scores. This finding indicates that vowels of final syllables in words with IGs have higher mean f0 than those in words without IGs, by 2.03 to 3.6 Hz. The effect of phrasal position is also significant, with an estimated effect size of approximately −1.28 z-scores. This finding indicates that vowels of final syllables in phrase-final position have lower mean f0 than those in phrase-medial position, by −28.8 to −51.2 Hz. The interaction of the presence of IGs and phrasal position also has a significant effect on mean f0, with an estimated effect size of approximately −0.09 z-scores. This finding indicates that the final syllable vowels in words with IGs have an additional decrease in mean f0 in phrase-final position, estimated to be −2.03 to −3.6 Hz.

Table 5. Summary of statistical analyses of f0 (significance and effect size)

	Initial geminates vs. singleton				$Vowel_1$ vs. $Vowel_2$	
	$Vowel_1$		$Vowel_2$		$Vowel_2 - Vowel_1$	
	Sig.	Est.	Sig.	Est.	Sig.	Est.
Geminate	***	0.01	***	0.09	n.s.	
Linear × Geminate	**	−0.07	n.s.			
Quadratic × Geminate	*	−0.05	**	−0.11		
Cubic × Geminate	**	0.07	n.s.			
Position	***	−0.24	***	−1.29	***	−0.66
Linear × Position	***	−0.17	***	−2.24		
Quadratic × Position	n.s.		***	0.33		
Cubic × Position	**	0.06	*	0.10		
Geminate × Position	*	0.01	***	−0.08	n.s.	
Linear × Geminate × Position	*	−0.07	***	0.57		
Quadratic × Geminate × Position	n.s.		***	0.27		
Cubic × Geminate × Position	n.s.		n.s.			

***p < .001, ** 0.001 < p < 0.01, * 0.01 < p < 0.05

No significant effect was observed for the interaction between linear time and the presence of IGs, but the effect of the interaction between linear time and position is significant, with an estimated effect size of approximately −2.24 z-scores (−50.4 to −89.6 Hz). The effect of interaction among linear time, the presence of IGs, and phrasal position is also significant, with an estimated effect size of approximately 0.57 z-scores (12.83–22.8 Hz). These findings indicate that position and the interaction of the presence of IGs and position affect the f0 slope but that the presence of IGs does not. Additionally, the interaction between quadratic time and the presence of IGs is significant. Similarly, the interaction between quadratic time and phrasal position is significant. The effect of the interaction among quadratic time, the presence of IGs, and position is also significant. No effect was observed for the interaction between cubic time with the presence of IGs or the interaction among cubic time, the presence of IGs, and position. The effect of the interaction of cubic time and position is significant. Figure 9 illustrates the model fit.

Finally, we conducted a comparison between initial and final syllable differences in f0. The best performing model is one with a term for position only ($\chi^2_{(1)} = 12.15$, $p < .001$). The results demonstrate that phrasal position influences the difference in f0 between the final and initial syllable and that phrase-final position reduces the difference in f0 between the final and initial syllables, with an estimated effect size of −0.66 z-scores (95% CI [−0.96, −0.36]); this finding corresponds to a range from −14.93 to −26.45 Hz (Figure 10).

Table 5 shows the summary of statistical analyses of f0.

5.4 Formants

We found no effects of the presence of IGs, phrasal position, or their interaction on either F1 ($\chi^2_{(3)} = 4.40$, $p = .22$) or F2 ($\chi^2_{(3)} = 1.24$, $p = .74$) of vowels in initial syllables. The presence of IGs and phrasal position, as well as their interaction had no effect on either the F1 ($\chi^2_{(3)} = 4.61$, $p = .20$) or F2 ($\chi^2_{(3)} = 3.13$, $p = .37$) of the vowels in final syllables.

5.5 Spectral tilt

A significant effect is observed for phrasal position on initial syllable vowel H1–A2 ($\chi^2_{(1)} = 6.63$, $p = .01$). In phrase-final position, initial syllable vowels have a larger H1–A2 than in phrase-medial position, with an estimated effect size of 2.25 dB (95% CI [0.95, 3.55] dB). There is also a significant effect of phrasal position on initial syllable vowels H1–A3 ($\chi^2_{(1)} = 4.95$, $p = .026$). In phrase-final position, initial syllable vowels have a larger H1–A3 than in phrase-medial position, with an estimated effect size of 2.45 dB (95% CI [0.73, 4.18]) (Figure 11). No significant effect is observed for the presence of IGs and the interaction between the presence of IGs and position.

Similar effects are found for the final syllable vowels. The effect of phrasal position on final syllable vowel H1–A2 is significant ($\chi^2_{(1)} = 5.89$, $p = .015$). In phrase-final position, final syllable vowels have a larger H1–A2 than in phrase-medial position, with an estimated effect size of 3.06 dB (95% CI [0.83, 5.30] dB). There is also a marginally significant effect of phrasal position on final syllable vowel H1–A3 ($\chi^2_{(1)} = 3.91$, $p = .048$). In phrase-final position, final syllable vowels have a larger H1–A3 than in phrase-medial position, with an estimated effect size of 2.49 dB (95% CI [0.19, 4.79] dB) (Figure 12). No significant effect is observed for the presence of IGs and the interaction between the presence of IGs and position.

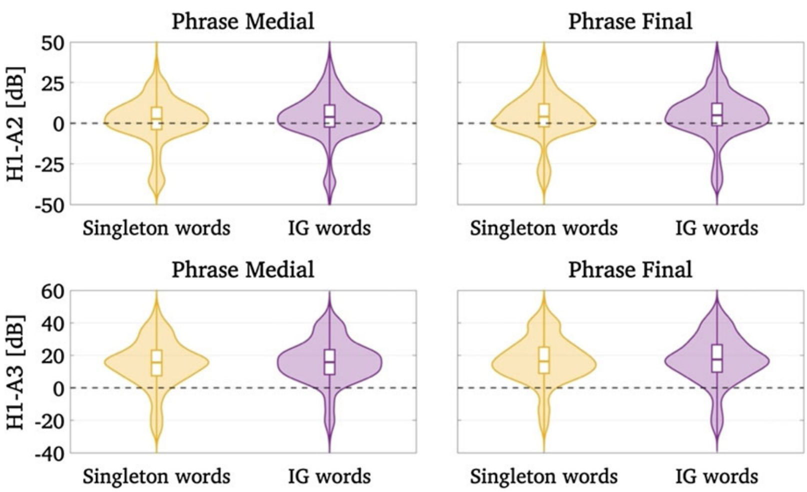

Figure 11. (Colour online) Left: H1–A2 (top) and H1–A3 (bottom) of initial syllable vowels in phrase-medial position. Right: H1–A2 (top) and H1–A3 (bottom) of initial syllable vowels in phrase-final position.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

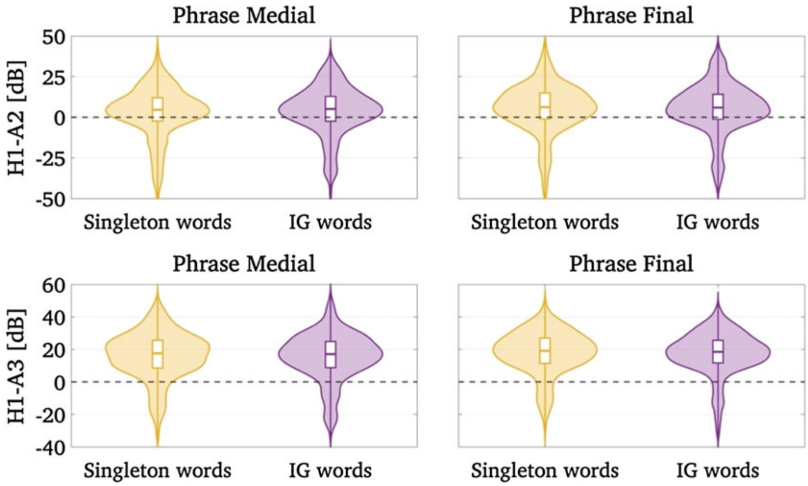

Figure 12. (Colour online) Left: H1−A2 (top) and H1−A3 (bottom) of final syllable vowels in phrase-medial position. Right: H1−A2 (top) and H1−A3 (bottom) of final syllable vowels in phrase-final position.

6 Discussion

We now return to our two research questions:

(i) Does the presence of IGs affect the prominence profile of PM words?

(ii) Does position in the utterance affect the prominence profile of PM words?

For (i), our experimental findings do not support the claim that the presence of IGs categorically affects the prominence profiles of PM words; instead, they have only small phonetic effects on syllable duration, intensity, and f0. Significant differences are not observed in the relative prominence profiles of words with and without IGs. For (ii), the presence of phrasal boundary has categorical effects on the relative f0 of initial and final syllables because words in phrase-medial position show a rising f0 contour, and words in phrase-final position show a falling f0 contour.

Initial syllables with IG onsets have a consistently higher syllable-to-word duration ratio than initial syllables without IG onsets. The analysis of onset raw duration and duration ratios suggests that the effect is due to IGs being longer than the corresponding singletons. A mirror image effect is observed in final syllables: final syllable duration ratios exhibit a small decrease when words contain IGs because IGs increase the raw duration of initial syllables. Nonetheless, final syllables always display a longer duration ratio to the word than initial syllables, regardless of the presence of IGs (Figure 13, top).

Initial geminates also have small effects on the intensity of the vowels after them, with the clearest effect occurring in phrase-final position where vowels after IGs have a higher intensity than those after singletons (Figure 13, middle). In other words, how strongly IGs affect intensity appears to be related to position in the phrase as well. In terms of relative prominence, intensity is always slightly higher on initial syllables than on final syllables, regardless of the presence of IGs. It is worth noting that prominent syllables are found to have higher intensity than non-prominent ones cross-linguistically (Gordon & Roettger 2017).

Similar increases due to the presence of IGs are observed for f0, but the effect size is even smaller. Furthermore, words with and without IGs do not have different f0 profiles in the

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

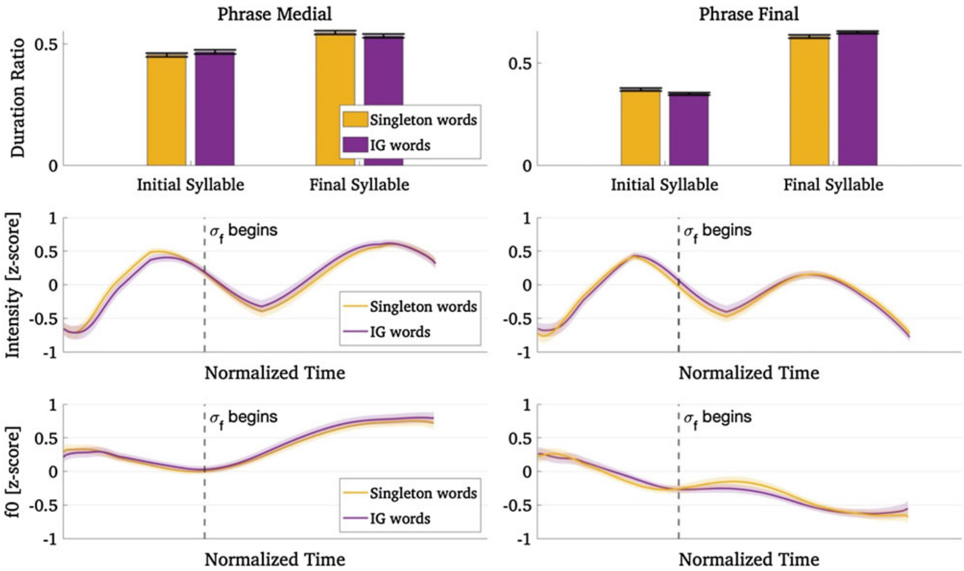

Figure 13. (Colour online) Duration ratio (top), intensity contour (middle), and f0 contour (bottom) of words with IG and singleton onsets.

same phrasal position (Figure 13, bottom). No effect of the presence of IGs is observed for vowel formants or spectral tilt. Overall, the presence of IGs has small effects corresponding to longer duration ratios and higher intensity on the vowel of the initial syllables, especially when the words appear phrase-finally, and a general increase in f0 for both the initial and final syllable vowels. These findings demonstrate that the effects of IGs are subtle and not in line with a phonological change of stress or pitch accent position.

By contrast, the effects of phrasal position are significantly stronger than the effect of the presence of IGs. Occurrence in phrase-final position strongly increases the raw duration of final syllables, decreasing the duration ratio of the initial syllable to the word, and the duration ratio of the final syllable to the word (Figure 13, top).

Phrasal position also correlates with categorical differences in intensity and f0 contours. Namely, words in phrase-final position have lower intensity and f0 for both initial and final syllable vowels than those in phrase-medial position (Figure 13, middle and bottom). We also found a stronger effect on the vowels in final syllables than on the vowels in initial syllables. The final syllable vowels in phrase-final position show a steeper intensity fall than final syllable vowels in phrase-medial position (Figure 13, middle). Similarly, final syllable vowels in phrase-final position show falling f0 contours, and final syllable vowels in phrase-medial position show rising f0 contours (Figure 13, bottom). It is important to note that the falling f0 contour in phrase-final position is commonly observed cross-linguistically. This phenomenon is known as f0 declination (Ladd 1984).

No effect on vowel formants is observed. We also observed an effect of phrasal position on the spectral tilt of initial and final syllable vowels. The H1−A2 and H1−A3 values are the most positive in phrase-final position. In other words, the decrease in energy from the first harmonic to the higher frequency range (A2 or A3) is larger when words appear in phrase-final position than when words appear in phrase-medial position. Based on previous reports of spectral tilt as a correlate of prominence (Gordon & Roettger 2017), our observation is that vowels of both initial and final syllables in phrase-final position seem to be similar to

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table 6. Direction of the effects of the presence of IGs and phrasal position on duration ratio, z-scored intensity, z-scored f0, vowel formants (Hz), H1−A2 (dB), and H1−A3 (dB). Significant effects are presented with their estimated effect size

	Singleton vs. initial geminate						Phrasal position					
	$V_i(-IG)$	$V_i(IG)$	Est.	$V_f(-IG)$	$V_f(IG)$	Est.	$V_i(M)$	$V_i(F)$	Est.	$V_f(M)$	$V_f(F)$	Est.
Duration	−	+	.015	+	−	−.015	+	−	−.1	−	+	.1
Intensity	=	=		−	+	.05	+	−	−.26	+	−	−.6
f0	−	+	.008	−	+	.08	+	−	−.24	+	−	−1.29
Formant	=	=		=	=		=	=		=	=	
H1−A2	=	=		=	=		−	+	2.25	−	+	3.06
H1−A3	=	=		=	=		−	+	2.79	−	+	2.49

less prominent vowels in that they have a steeper intensity roll-off. Table 6 summarizes the effects of the presence of IGs and phrasal position.

In summary, the effects of IGs are less salient than those of phrasal position; this finding is evident from the difference in the order of magnitude of the effects. Moreover, the effects of IGs seem to be amplified in phrase-final position, thus, showcasing a hitherto unnoticed interesting interaction between these two factors.

Based on our experimental results, one open question is why PM has been reported to have final stress and stress shift in words with IGs (e.g., Chotikakamthorn 1981; Yupho 1989). Previous studies (Section 1.2) elicited PM words in isolation or as a final word in a carrier sentence. In other words, the prominence patterns reported in the literature reflect prominence in phrase-final position. Our study shows that the presence of IGs has stronger effects when words appear in phrase-final position. We found intensity and f0 boosts due to the presence of IGs on initial syllable vowels in phrase-final position. In phrase-medial position no intensity boost and a less strong f0 boost on initial syllable vowels are observed. The presence of a phrase-final boundary decreases the intensity and f0 of final syllable vowels in words with IGs, even more than it does in words without IGs (Table 4 and Table 5). Thus, in phrase-final position, words with IGs have higher intensity and f0 on initial syllables than words without IGs. However, on final syllables, the values are comparable. Combining these two effects, we observed that words with IGs show a steeper fall of intensity and f0 over the word than words without IGs in phrase-final position.

In view of these findings, one possibility is that previous reports of categorical effects of IGs are due to the steeper falling f0 and intensity profiles compared to words with singletons. This sharper fall may lead to the perception of a stress shift, especially for native speakers of Thai (e.g., Chotikakamthorn 1981; Yupho 1989), who perceive falling contours as posttonic (Gandour 1979). If researchers have been assuming that PM is a non-tonal language and somewhat similar to a prototypical stress language, like English, the higher pitch and intensity on the initial syllable and the sharp falling contour in IG words may have been interpreted as stress on the initial syllable, especially by Thai field linguists. Additionally, because words were possibly elicited in isolation, that is, phrase-finally, final lengthening of the final syllable may be perceived as stress in non-IG words, where initial syllables have lower intensity and f0 and a less steep falling contour over the word.

We conclude with a final remark on perhaps the single most famous claim on PM IGs, namely, their alleged moraic status (Hajek & Goedemans 2003; Topintzi 2008). In previous work, PM IGs have been described as a case of moraic onset, based on the claim that IGs attract stress: words with IGs have initial stress, while final stress is the default. However, our data suggest that IGs do not affect prominence profiles of words in PM in the categorical manner predicted by this account. Our findings cast doubt on the claim that PM IGs trigger a stress shift. This, in turn, invalidates the only positive evidence for the moraic status of IGs in PM. Regarding stress or prominence, our findings suggest that PM is more similar to most Malay varieties in lacking clear evidence for stress and the contemporaneous usage of f0 and other acoustic cues typically attributed to word-level prominence.

Some limitations of the present work should also be acknowledged. First, our data collection procedures and stimuli are more typical of a corpus collection rather than tightly controlled lab speech. Additional limitations result from a tradeoff between constructing natural sounding PM sentences and control over stimuli and carriers of segmental composition. For instance, differences in length of the carrier sentence, the use of different vowels across initial syllables, as well as in initial and final syllables of the same word, are all factors that introduce more variability in measurements like duration, due to compression in longer sentences, and f0 and intensity, due to intrinsic f0 and intensity effects. At the same, they also prevent us from conducting certain analyses, like a comparison of formants across the two vowels in the same word. We tried to account for this type of variation by presenting both raw and normalized measurements, like ratios and deltas. Furthermore, we also included random effects in the model that capture word-specific variations due to segmental composition and context, as each word is embedded in a unique context.

A final disclaimer worth emphasizing is that this paper presented only (acoustic) production evidence. Acoustic evidence seems to broadly agree with previous reports of longer duration, higher f0, and intensity (only in phrase-final position) after IGs. The effects do not seem, however, to be compatible with previous claims of suprasegmental changes to words in the presence of IGs; as the acoustic profiles of words with and without IGs are comparable. Perceptual work is, however, necessary, to ascertain how the acoustic patterns reported may be mapped to the perception of phonological contrasts in PM both in terms of segmental and of suprasegmental information, as well as their interaction. Especially given that recent work has shown that the perception of cues to duration is modulated by prosody (e.g., Steffman 2019). However, this will not be an easy task given the complex interplay of acoustic cues underlying IGs contrasts in PM (Abramson 1986, 2003) and cross-linguistically (Burroni et al. 2022).

Despite these limitations, our results broadly confirm the findings of previous work where IGs, examined in words recorded in isolation, caused increases in f0 and intensity over the vowels following them. This is in line with acoustic work on IGs in other languages, where concomitant changes in f0 and intensity are also present (Burroni et al. 2022), but no stress shift process in their presence has been alleged. Our work additionally contributed by showing that some of these effects are probably due to the interaction of IGs and prosodic boundaries, which was not examined in previous work. In sum, both tightly controlled and more naturalistic speech point in the same direction. Future work on PM could be dedicated to uncovering how the differences between IGs and singletons may vary as a function of communicative context, for instance, in the presence of an interlocutor or in different speech tasks.

7 Conclusion

In this paper, we have studied the interaction between syllabic prominence, the presence of IGs, and phrasal boundaries in PM. We conclude that IGs do not trigger categorically different prominence profiles as claimed in the literature, but do correspond to a subtle acoustic modulation of duration, intensity, and f0. Additionally, a phrasal boundary triggers categorical changes that can be considered phonological effects, as shown by the difference in duration, intensity, f0, and spectral tilt. We also uncovered an interaction between IGs and prosodic boundaries, which may be responsible for the perception of stress shift reported in the literature. Our acoustic investigation has also allowed us to contextualize PM among other Malay varieties. PM looks similar to other Malay varieties, for example, Besemah and Malaysian Malay, in which duration and f0 contours are dissociated from each other. In summary, we conclude that PM is less typologically exceptional than previously claimed in the phonological literature.

Acknowledgment This study is built upon findings from a distinct pilot project concluded in 2014 and financially supported by the Ratchadaphiseksomphot Endowment Fund of Chulalongkorn University (RES560530179-HS). We are especially grateful to Jakrabhop Iamdanush for his essential involvement in the pilot project, to D. Robert Ladd for his insightful comments, and to the audiences at the twenty-fourth Annual Meeting of the Southeast Asian Linguistic Society and seventeenth Conference on Laboratory Phonology for their valuable feedback. We extend our thanks to the associate editor at JIPA and the anonymous reviewers for their constructive insights. Our gratitude also goes to Ruslan Uthai and Santhawat Thanyawong for their assistance in connecting with the community and facilitating the fieldwork, to Nur Ida ibni Sulaiman for providing valuable resources, and to the Faculty of Humanities and Social Sciences, Prince of Songkhla University, Pattani Campus, for allowing us to use their space to conduct the fieldwork. We appreciate Nirohani Chansang, Haphifi Sama-ae, and Kanura Aphibanbae for their language input, and all the participants for generously contributing their time and patience.

Author contribution This research article is the outcome of a collaborative effort among all the listed authors. Burroni and Maspong contributed equally to this work and share first authorship, while Pittayaporn is the principal investigator. All four authors has made substantial contributions to the conception, design, execution, and interpretation of the research work. For clarity and to facilitate academic recruitment processes, individual author responsibilities are delineated as follows:

Francesco Burroni: Sections 4.3, 4.4, 5.1, 5.3, 5.4, 6
Sireemas Maspong: Sections 2.1, 2.2, 3, 4.3, 4.4, 5.2, 5.5
Pittayawat Pittayaporn: Sections 1, 2.1, 7
Pimthip Kochaiyaphum: Sections 4.1, 4.2

While the aforementioned divisions are indicative of the primary contributions, it is important to emphasize that the collaborative nature of this work involved iterative discussions, mutual feedback, and collective decision-making among all authors. As such, the final manuscript represents the synergistic efforts of the entire team.

Appendix A

Table A1. Prompts

PM	Gloss	Final position	Non-final position
[pagi]	'morning'	baŋuŋ pagi	magɛ nasi pagi tɯŋa gɛŋsom
		(I) wake up in the morning.	I have Kangsom (curry) for breakfast.
[paka]	'to use/wear'	tajɔ/ʔamɔ/kitɔ kɨnɛ tali taŋɛ hɔʔ dɛmɔ paka.	ʔamɔ paka tali taŋɛ
		I like the bracelet that I wear.	I wear a bracelet.
[tanɔh]	'land'	tɔʔ tanɔh	dalɛ tanɔh ʔadɔ ɟaɟiŋ
		(I) put it on the ground.	There are earthworms in the ground.
[dapo]	'kitchen'	ɣumɔh ʔadɔ dapo duwɔ dapo	ʔadɔ dapo bɯsa tɯŋa dapo haluh
		There is a kitchen in a house.	There are big and small kitchens.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table A1. Continued

PM	Gloss	Final position	Non-final position
[katoʔ]	'hammer'	pitu salɔʔ paka tuko katoʔ A door was locked. (We) must use a hammer to smash it.	ʔamɔ paka tuko katoʔ pitu I use a hammer to smash the door.
[kabo]	'Java kapok'	dijɔ tanɛ pahaŋ kabo He plants a Java kapok tree.	paka kabu buwa bata The pillow is made of Java kapok.
[gaɟi]	'wage'	tajɔ buleh duwi gaɟi I receive my salary.	ʔaku gaɟi kɔ dɛmɔ I pay you (your) salary.
[ɟalɛ]	'path'	ʔamɔ digɔ ɟalɛ There are three paths.	ʔadɔ ɟalɛ digɔ ɟalɛ There are paths; three of them.
[misa]	'mustache'	tajɔ ɟuko misa I shave (my) mustache.	tajɔ ɟuko misa sɔʔmɔ I usually shave (my) mustache.
[labɔ]	'profit'	juwa buleh labɔ I gain profit from selling.	juwa buleh labɔ bajɔʔ I gain a lot of profit from selling.
[bulɛ]	'moon'	malɛ ʔadɔ bulɛ There is the moon at night.	sɨmalɛ bulɛ ɟɨkɔʔ Last night the moon was bright.
[buŋɔ]	'flower'	ʔamɔ sukɔ buŋɔ I like flowers.	ʔamɔ sukɔ buŋɔ puteh I like white flowers.
[ɟuɣi]	'to steal'	jɔ katɔ ʔaku ɟuɣi His necklace is missing, (and) he thinks that I stole it.	dijɔ ɟuɣi talitɨkɔʔ hɔh ʔamɔ He stole my necklace.
[pːagi]	'early morning'	dɛŋɔ baŋuŋ pːagi You wake up very early in the morning.	buwa nasi pːagi duwa mɔʔ I cook with mom early in the morning.
[pːaka]	'usable'	computer tu buleh pːaka That computer works.	ʔamɔ buleh pːaka computer tu You can use that computer.
[tːanɔh]	'outside/ on the floor'	sajɔ ta tːanɔh (It is) outside/on the floor (of the house).	tanɛ buŋɔ tːanɔh dɔh Flowers were already planted outside/on the floor.
[dːapo]	'at the kitchen'	mɛ buwa nasi dalɛ dːapo (My) mother was cooking in the kitchen.	mɛjɔ dːapo punɔh A table in the kitchen is broken.
[kːatoʔ]	'frog'	ʔamɔ juwa kːatoʔ I sell frogs.	ʔamɔ ʔadɔ kːatoʔ paʔ ʔɛkɔ I have four frogs.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Table A1. Continued

PM	Gloss	Final position	Non-final position
[kːabo]	'beetle'	ʔamɔ pɛɣɔ kːabo I have beetles (as pets).	ʔamɔ pɛɣɔ kːabo paʔ ʔɛkɔ I have four beetles.
[gːaɟɨ]	'saw'	dijɔ nɔh gːaɟi He wants a saw.	kitɔ paka gːaɟi gɨɣaʔ pahoŋ We use a saw to cut trees.
[ɟːalɛ]	'to walk'	sajɔ ɟːalɛ I walk.	mɛ ɟːalɛ ɣigɨ nah (My) mother walks to the market.
[mːisa]	'to grow a mustache'	jatɛ taŋoʔ mːisa Men like to keep mustache.	ʔabɛ tako mːisa paɲɛ He keeps a very long mustache.
[lːabɔ]	'spider'	ʔamɔ takoʔ lːabɔ I am afraid of spiders.	ʔadɔ lːabɔ pitu There is a spider at the door.
[bːulɛ]	'month'	dijɔ ɣi wagijɔ hatjai duwɔ bːulɛ He works at Hatyai for two months.	sa bːulɛ ʔadɔ tiɣɔpuloh haɣi There are thirty days in a month.
[bːuŋɔ]	'to bloom'	buŋɔ bːuŋɔ Flowers bloom.	buŋɔ bːuŋɔ puteh Flowers bloom in white.
[ɟːuɣi]	'thief'	dijɔ jadi ɟːuɣi He is a thief.	sɨdadu ʔiɣa ɟːuɣi paʔ ʔɛkɔ Four thieves were arrested by the police.

Appendix B

Statistical models (Best fitting models)

Duration Onset Duration ~ IG + (IG |Speaker) + (IG|Onset Voicing/Place/Manner)

Onset Duration Ratio ~ IG + Position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner)

Syllable 1 Ratio ~ IG + Position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner)

Syllable 2 Ratio ~ IG + Position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner)

Delta Syllable 2 - Syllable 1 Ratio ~ IG + Position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner)

Intensity Delta Syllable 2 - Syllable 1 Intensity ~ IG * Position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner) + (IG + Position|Vowel)

Formants V1/2 F1/F2 ~ 1 _(IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner) + (IG + Position|Vowel)

Spectral tilt V1/2 H1–A2/H1–A3 ~ position + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner) + (IG + Position|Vowel)

Delta V1–V2 H1–A2/H1–A3 ~ 1 + (IG + Position|Speaker) + (IG + Position|Onset Voicing/Place/Manner) + (IG + Position|Vowel)

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

References

Abramson, Arthur S. 1986. The perception of word-initial consonant length: Pattani Malay. *Journal of the International Phonetic Association* 16(1), 8–16.

Abramson, Arthur S. 1987. Word-initial consonant length in Pattani Malay. *International Congress of Phonetic Association* 6, 68–70.

Abramson, Arthur S. 1998. The complex acoustic output of a single articulatory gesture: Pattani Malay word-initial consonant length. In Udom Warotamasikkhadit and Thanyarat Panakul (eds.), *Papers from the Fourth Annual Meeting of the Southeast Asian Linguistics Society*, 1–20, Arizona State University, Program for Southeast Asian Studies.

Abramson, Arthur S. 2003. Acoustic cues to word-initial stop length in Pattani Malay. In Maria-Josep Solé, Daniel Recasens & Joaquin Romero (eds.), *Proceedings of the 15th International Congress of Phonetic Sciences (ICPhS XV)*, Universitat Autònoma de Barcelona, Barcelona, 387–390.

Abramson, Arthur S. 2004. Toward prosodic contrast: Suai and Pattani Malay, In Bernard Bel & Isabelle Marlien (eds.), *International Symposium on Tonal Aspects of Languages: Emphasis on Tone Languages*. The Institute of Linguistics, Chinese Academy of Social Science, Beijing, 1–4.

Atal, Bishnu S. 1972. Automatic speaker recognition based on pitch contours. *Journal of the Acoustical Society of America* 52, 1687–1697.

Boersma, Paul & David Weenink. 2020. Praat: Doing phonetics by computer (version 6.1.12). Available at: www.praat.org/ [last accessed 21 September 2023].

Burroni, Francesco, Raksit Lau-Preechathammarach & Sireemas Maspong. 2022. Unifying initial geminates and fortis consonants via laryngeal specification: Three case studies from Dunan, Pattani Malay, and Salentino, In Peter Jurgec, Liisa Duncan, Emily Elfner, Yoonjung Kang, Alexei Kochetov, Brittney K. O'Neill, Avery Ozburn, Keren Rice, Nathan Sanders, Jessamyn Schertz, Nate Shaftoe, & Lisa Sullivan (eds.), *Proceedings of the 2021 Annual Meeting on Phonology*, 1–13. Washington, DC: Linguistic Society of America.

Burroni, Francesco, Sireemas Maspong, Pittayawat Pittayaporn & Pimthip Kochaiyaphum. 2020. A new look at Pattani Malay Initial Geminates: A statistical and machine learning approach. In *Proceedings of the 34th Pacific Asia Conference on Language, Information and Computation*, 21–29. Hanoi: Association for Computational Linguistics.

Byrd, Dani & Elliot Saltzman. 2003. The elastic phrase: Modeling the dynamics of boundary-adjacent lengthening. *Journal of Phonetics* 31(2), 149–180.

Chotikakamthorn, Maneerat. 1981. *A comparative study of phonology in Satun Malay and Pattani Malay*. Master's thesis, Mahidol University.

Cohn, Abigail C. 1989. Stress in Indonesian and bracketing paradoxes. *Natural Language & Linguistic Theory* 7(2), 167–216.

Collins, James T. 1989. Malay dialect research in Malaysia: The issue of perspective. *Bijdragen tot de Taal-, Land- en Volkenkunde. Journal of the Humanities and Social Sciences of Southeast Asia and Oceania* 145(2), 235–264.

Davis, Stuart. 2011a. Quantity. In John Goldsmith, Jason Riggle & Alan C. L. Yu (eds.), *The handbook of phonological theory*, 2nd edn, 103–140. Chichester and Malden, MA: Wiley-Blackwell.

Davis, Stuart. 2011b. Geminates. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume & Keren Rice (eds.), *The Blackwell companion to phonology*, vol. 1, 837–859, Malden, MA & Oxford: Wiley-Blackwell.

Edwards, Jan, Mary E. Beckman & Janet Fletcher. 1991. The articulatory kinematics of final lengthening. *The Journal of the Acoustical Society of America* 89(1), 369–382.

Frigo, Matteo & Steven G. Johnson. 1998. FFTW: An adaptive software architecture for the FFT. In *The 1998 IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 3, 1381–1384, Seattle.

Gałecki, Andrzej & Burzykowski Burzykowski. 2013. *Linear mixed-effects models using R: A step-by-step approach (Springer Texts in Statistics)*. New York, NY: Springer.

Gandour, Jack. 1979. Tonal rules for English loanwords in Thai. In Theraphan Luangthongkam (ed.), *Studies in Tai and Mon-Khmer phonetics and phonology in honour of E. J. A. Henderson*, 94–105. Bangkok: Chulalongkorn University Press.

Goedemans, Rob & Ellen van Zanten. 2007. Stress and accent in Indonesian. *Prosody in Indonesian Languages*, 35–62. Ultrecht: LOT.

Gordon, Matthew. 2014. Disentangling stress and pitch-accent: A typology of prominence at different prosodic levels. *Word stress: Theoretical and typological issues*, 83–118. Cambridge: Cambridge University Press.

Gordon, Matthew & Timo Roettger. 2017. Acoustic correlates of word stress: A cross-linguistic survey. *Linguistics Vanguard* 3(1), 20170007.

Hajek, John & Rob Goedemans. 2003. Word-initial geminates and stress in Pattani Malay. *The Linguistic Review* 20(1), 79–94. https://doi.org/10.1515/tlir.2003.003

Halim, Amran. 1974. *Intonation in relation to syntax in Bahasa Indonesia*. Jakarta: Djambatan.

Hamzah, Hilmi. 2013. *The acoustics and perception of the word-initial singleton/geminate contrast in Kelantan Malay*. Doctoral dissertation, University of Melbourne.

Hamzah, M. Hilmi, Janet Fletcher & John Hajek. 2011. Durational correlates of word-initial voiceless geminate stops: The case of Kelantan Malay. In Wai Sum Lee & Eric Zee (eds.), *Proceedings of the 17th International Congress of Phonetic Sciences* (ICPhS XVII), 815–818. Hong Kong: City University of Hong Kong.

Hamzah, M. Hilmi, Janet Fletcher & John Hajek. 2014. Amplitude and f0 as acoustic correlates of Kelantan Malay word-initial geminates. In Jennifer Hay & Emma Parnell (eds.), *Proceedings of the 15th Australasian International Conference on Speech Science and Technology*, 63–66. Christchurch: Australian Speech Science and Technology Association.

Heuven, Vincent J. van, Lilie M. Roosman & Ellen van Zanten. 2008. Betawi Malay word prosody. *Lingua* 118, 1271–1287.

Heuven, Vincent J. van & Ellen van Zanten (eds.). 2007. *Prosody in Indonesian languages*. Utrecht: LOT.

Huang, Xuedong, Alex Acero & Hsiao-Wuen Hon. 2001. *Spoken language processing: A guide to theory, algorithm, and system development*. Upper Saddle River, NJ: Prentice Hall PTR.

Iemwanthong, Kanyarat. 2008. *Acoustic characteristics of Pattani Malay vowels*. Master's thesis, Chulalongkorn University.

Kaland, Constantijn. 2019. Acoustic correlates of word stress in Papuan Malay. *Journal of Phonetics* 74, 55–74.

Kaland, Constantijn. 2021. The perception of word stress cues in Papuan Malay: A typological perspective and experimental investigation. *Laboratory Phonology. Open Library of Humanities* 12(1), 1–33.

Kaland, Constantijn & Stefan Baumann. 2020. Demarcating and highlighting in Papuan Malay phrase prosody. *Journal of Acoustical Society of America* 147(4), 2974–2988.

Kluge, Angela. 2017. *A grammar of Papuan Malay* (Studies in Diversity *Linguistics*), vol. 11. Berlin: Language Science Press.

Kraehenmann, Astrid. 2011. Initial geminates. In Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume, & Keren Rice (eds.), *The Blackwell companion to phonology*, vol. 2, 1124–1146. Oxford: Wiley-Blackwell.

Kraehenmann, Astrid & Aditi Lahiri. 2008. Duration differences in the articulation and acoustics of Swiss German word-initial geminate and singleton stops. *Journal of the Acoustical Society of America* 123, 4446–4455.

Krisnapan, Daranee. 1985. *A phonology of Taba Malay*. Master's thesis, Mahidol University.

Ladd, D. Robert. 1984. Declination: A review and some hypotheses. *Phonology Yearbook* 1, 53–74.

Maskikit-Essed, Raechel & Carlos Gussenhoven. 2016. No stress, no pitch accent, no prosodic focus: The case of Ambonese Malay. *Phonology* 33, 353–389.

MATLAB. 2021. version *9.10.0.1602886 (R2021a)*. Natick, MA: The MathWorks Inc.

McAuliffe, Michael, Michaela Socolof, Sarah Mihuc, Michael Wagner & Morgan Sonderegger. 2017. Montreal Forced Aligner. Available at: http://montrealcorpustools.github.io/Montreal-Forced-Aligner/ [last accessed 21 September 2023].

McDonnell, Bradley. 2016. Acoustic correlates of stress in Besemah. *NUSA: Linguistic studies of languages in and around Indonesia* 60, 1–28.

Mirman, Daniel. 2014. *Growth curve analysis and visualization using R*. Boca Raton, CA: Chapman & Hall/CRC the R series.

Mohd Don, Zuraidah, Gerry Knowles & Janet Yong. 2008. How words can be misleading: A study of syllable timing and "stress" in Malay. *Linguistics Journal* 3(2), 66–81.

Muller, Jennifer. 2001. *The phonology and phonetics of word-initial geminates*. Ph.D. dissertation, Ohio State University.

National Statistical Office. 2012. *The 2010 population and housing census: Southern region*. Bangkok: National Statistical Office.

Pakkhem, Siriwan. 2007. *A phonological comparison of Pattani Malay as spoken in Narathiwat, Krabu and Pathumthani*. Master's thesis, Mahidol University.

Paramal, Waemaji. 1991. *Long consonants in Pattani Malay: The result of word and phrase shortening*. Master's thesis, Mahidol University.

Phuengnoi, Nattaphon. 2010. *An acoustic study of stressed and unstressed syllables in Pattani Malay and Urak Lawoi*. Master's thesis, Chulalongkorn University.

Pittayaporn, Pittayawat & Jakrabhop Iamdanush. 2014. Metrical stress in Pattani Malay. Presented at the *24th Annual Meeting of Southeast Asian Linguistics Society*.

Poonsub, Areeluk. 2016. The linguistic identity factors in the question of Southern border provinces: Some policy recommendations for the Thai state. In Suphatmet Yunyasit (ed.), *Collections of studies in the linguistic status in Southern border provinces*, 157–181. Nakornpathom: Institute of Human Rights and Peace Studies, Mahidol University.

Premsrirat, Suwilai & Mirinda Burarungrot. 2018. Patani Malay-Thai bi/multilingual education in Thailand's Deep South. In Suwilai Premsrirat & David Hirsh (eds.), *Language revitalization: Insights from Thailand*, 239–250. Bern: Peter Lang.

https://doi.org/10.1017/S0025100323000233 Published online by Cambridge University Press

Premsrirat, Suwilai & Mirinda Burarungrot. 2022. Multilingualism, bi/multilingual education and social inclusion: A case study in Southern Thailand. *MANUSYA: Journal of Humanities* 24(3), 373–389.
Ridouane, Rachid. 2007. Gemination in Tashlhiyt Berber: An acoustic and articulatory study. *Journal of the International Phonetic Association* 37, 119–142.
Ringen, Catherine & Robert M. Vago. 2010. Geminates: Heavy or long? In Charles Cairns & Eric Raimy (eds.), *Handbook of the syllable*. Leiden: Brill.
Smalley, William A. 1994. *Linguistic diversity and national unity: Language ecology in Thailand*. Chicago, IL: University of Chicago Press.
Steffman, Jeremy. 2019. Phrase-final lengthening modulates listeners' perception of vowel duration as a cue to coda stop voicing. *Journal of Acoustical Society of America* 145, EL560–EL566.
Topintzi, Nina. 2008. On the existence of moraic onsets. *Natural Language and Linguistic Theory* 26, 147–184.
Topintzi, Nina. 2010. *Onsets: Suprasegmental and prosodic behaviour*. Cambridge, UK and New York, NY: Cambridge University Press.
Topintzi, Nina. 2016. Iquito: The prosodic colon and evaluation of OT stress accounts. In Jeffrey Heinz, Rob Goedemans & Harry van der Hulst (eds.), *Dimensions of phonological stress*, 123–167. Cambridge: Cambridge University Press.
Topintzi, Nina & Stuart Davis. 2017. On the weight of edge geminates. In Haruo Kubozono (ed.), *The phonetics and phonology of geminate consonants*, 260–282. New York, NY: Oxford University Press.
Topintzi, Nina & Andrew I. Nevins. 2017. Moraic onsets in Arrernte. *Phonology* 34(4), 615–650.
Turk, Alice E. & Stefanie Shattuck-Hufnagel. 2007. Multiple targets of phrase-final lengthening in American English words. *Journal of Phonetics* 35(4), 445–472.
Uthai, Ruslan. 1993. *A comparison of word formation in standard Malay and Pattani Malay*. Bangkok: Chulalongkorn University.
Uthai, Ruslan. 2011. *Keistimewaan dialek Malayu Patani*. Bangi: Penerbit Universiti Kebangsaan Malaysia.
Wightman, Colin W., Stefanie Shattuck-Hufnagel, Mari Ostendorf & Patti J. Price. 1992. Segmental durations in the vicinity of prosodic phrase boundaries. *The Journal of the Acoustical Society of America* 91(3), 1707–1717. https://doi.org/10.1121/1.402450.
Yao, Yao, Sam Tilsen, Ronald L. Sprouse & Keith Johnson. 2010. Automated measurement of vowel formants in the Buckeye Corpus. *UC Berkeley PhonLab Annual Report* 6.
Yupho, Nawanit. 1989. Consonant clusters and stress rules in Pattani Malay. *Mon-Khmer Studies* 15, 125–137.

Cite this article: Burroni Francesco, Maspong Sireemas, Pittayaporn Pittayawat, and Kochaiyaphum Pimthip (2024). An exploratory investigation of interactions between syllabic prominence, initial geminates, and phrasal boundaries in Pattani Malay. *Journal of the International Phonetic Association* **54**, 264–293. https://doi.org/10.1017/S0025100323000233