ISCA Archive
http://www.isca-speech.org/archive

4th International Symposium on
Tonal Aspects of Languages (TAL-2014)
Nijmegen, The Netherlands
May 13-16 2014

# Non-Local Consonant-Tone Interaction in Thai

*Jeremy Perkins*

Center for Language Research, University of Aizu, Japan
jperkins@u-aizu.ac.jp

## Abstract

This paper presents a phonological account of consonant-tone sequence restrictions in Thai, positing a pair of new constraints, *[+CG]-[H]μ2 and LIC-T-Rt. *[+CG]-[H]μ2 restricts sequences of consonants and tones non-locally, referring instead to the notion of "head mora" of a syllable. LIC-T-Rt prefers a single tone to be right-aligned rather than left-aligned. Previous phonological accounts [9, 14] assumed that only high tone is banned following [+Constricted Glottis] ([+CG]) onsets in CV: syllables. However, new evidence based on a quantitative lexical analysis [12] has shown that sequences of [+CG] consonants followed by rising tone do not occur in CV: syllables in Thai. High and rising tone both contain late H targets phonetically, and so a new restriction is posited where [+CG] onsets are banned preceding H tone, only when the H tone is linked to the second mora within the syllable. This constraint is motivated since late tonal targets are cross-linguistically preferred over early ones [4, 18, 19]. The constraint, LIC-T-Rt, embodies this late tonal preference by exerting a preference to be right-aligned. The consonant-tone restriction can thus be viewed as a case where the syllable's tonal value is carried by the second mora, which acts as the "head" mora for the syllable.

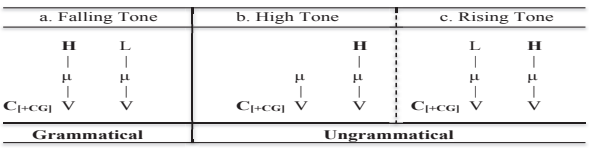
**Index Terms**: tone, Thai, Optimality Theory, consonant-tone interaction

## 1. Introduction

Few formal accounts of consonant-tone interaction exist. This paper offers a formal OT-account for consonant-tone interaction in Thai based on new results from acoustic, perceptual and lexical frequency studies in [12]. Previous accounts from [9, 10, 14] have assumed that only high tone is banned following [+CG] onset consonants; however results of a perception experiment and a lexical frequency study show that rising tone is similarly banned [12]. In light of this information, a new phonological analysis is proposed.

High and rising tone can be grouped together because they both involve late H-tone targets. While rising tone involves a rise from L to H, high tone involves a more shallow rise from M to H [12]. This phonetic similarity is posited to be the source for a single phonological ban: H tone in the 2nd mora following a [+CG] onset is banned. The constraint *[+CG]-[H]μ2 embodies this. The locality situation is summarized in Table 1 below.

Table 1. *Locality in consonant-tone interaction in Thai unchecked syllables.*




This result seems surprising, given usual assumptions where consonant-tone interaction is thought to be local, based on phonetic coarticulatory effects between an adjacent consonant and a vowel. For example, in Thai, we might expect falling tone to be banned following [+CG] onsets, since the H tone falls on the first mora, which is adjacent to the onset consonant. As Table 1 shows though, falling tone is attested following [+CG] onsets.

However, in phonology, we fully expect to see non-local effects, and it is argued that Thai is one such case. It is argued that the second mora is the "head" mora of the syllable in Thai. As such, the tonal value of the syllable is set to that of the second mora, and this value determines the grammaticality of the consonant-tone sequence.

## 2. Background

Thai has five contrastive tones: High, mid, low, rising, and falling [1, 2, 3, 6, 7]. Importantly, high tone actually rises from mid to high, so it is not actually a level tone [12](131-133, fig. 4 & 5). Not all possible combinations of onset and tone are possible within the same syllable, as shown in Table 2 below. The exact nature of the reported restriction seen in Thai depends on which of two classes the syllable belongs to; so-called "unchecked" syllables refer to those with no coda or with a sonorant coda (including CV:, CV:N and CVN, where N stands for any sonorant coda, here and elsewhere). So-called "checked" syllables refer to those with an obstruent coda (including CV:T and CVT, where T stands for any unaspirated obstruent). A different set of restrictions hold in checked syllables, but this paper will focus on effects in unchecked syllables only.

[14] noted that high tone never occurs on a vowel following voiced or voiceless unaspirated stops or affricates. [9, 10, 14] analyzed this as a phonological restriction against sequences of [–Spread Glottis] onsets followed by high tone. [12] noted that in addition, rising tone does not occur following these same onset consonants. This situation is summarized in Table 2 below. Here and throughout, "T" refers to any voiceless unaspirated stop or affricate. "D" refers to any voiced stop. "$C_{else}$" refers to all other consonants other than these (this includes aspirated stops, fricatives and all sonorants).

Table 2. *Consonant-tone restrictions in Thai unchecked syllables.*

| Onset | Mid Tone | Low Tone | Falling Tone | High Tone | Rising Tone |
|---|---|---|---|---|---|
| $C_{else}$ | ✓ | ✓ | ✓ | ✓ | ✓ |
| T | ✓ | ✓ | ✓ | ✗ | ✗ |
| D | ✓ | ✓ | ✓ | ✗ | ✗ |

## 3. Evidence

Recent results from [12] suggest that a pair of crucial assumptions made in previous phonological accounts of Thai

consonant-tone interaction are incorrect. Changing these assumptions then leads to a change in the phonological account, outlined in the next section.

First, not only high tone, but also rising tone is ungrammatical in unchecked syllables with voiced stop onsets or with voiceless unaspirated stop onsets [5, 9, 12, 14, 16, 17]. A quantitative analysis of Thai lexical gaps was conducted that confirmed that rising tone is equally unattested following voiced and voiceless unaspirated onsets. Additionally, a perception experiment confirmed that Thai speakers judge nonce words that contain sequences of [+CG] onsets followed by rising and high tone as worse than those with attested consonant-tone sequences. As a result, it is concluded that both high and rising-tone are ungrammatical following voiced and unaspirated voiceless onsets.

The second change is that the nature of the active consonant feature, assumed to be [–Spread Glottis] previously, is actually [+Constricted Glottis]. An acoustic study found that both unaspirated and voiced stops are accompanied by significant glottal constriction; no other onsets are accompanied by such glottal constriction in Thai. This suggests that these sounds form a natural class under the feature value [+Constricted Glottis] ([+CG]), and that [+CG] is the active phonological feature that is involved in the consonant-tone restriction in Thai.

## 3.1. [+CG]–rising tone sequences are ungrammatical

### *3.1.1. Evidence from Lexical Frequency*

This section offers a quantitative approach to confirm the status of a lexical gap involving consonant-tone sequences in Thai syllables. An online Thai dictionary [15] and a written Thai corpus [8] are analyzed in order to confirm the gaps.

Lexical frequencies reported here are for the total number of monosyllables that are attested words of Thai. An excel spreadsheet was populated with all 32,110 [1] possible monosyllables that can be built with the Thai inventory of segments, tone and vowel length. The spreadsheet included a field encoding whether the monosyllable was an attested word in Thai or not, to facilitate frequency calculations.

In addition to the dictionary, type frequencies were calculated from the ORCHID Thai text corpus [8]. The ORCHID corpus is a text corpus taken from Thai technical and scientific journals. The corpus contains approximately 400,000 words all in Thai orthography. It was translated into IPA via a Ruby script, in order to allow lexical analysis based on phonemic distinctions. Thai orthography correlates closely to phonetic pronunciation, so that this translation is feasible for monosyllabic words.

Loan words and onomatopoeia are exceptional, in that they do contain sequences of [+CG] onsets and high tone [14]. Therefore, the lexical statistics for the dictionary are shown below with loans and onomatopoeia filtered out in Table 3 below.

Table 3 below lists the number of attested monosyllabic words, classified by syllable type and tone in the dictionary search. The shaded cells indicate combinations of syllable-type and tone that are claimed to be ungrammatical here. For a given cell in the tables below, two values are listed: On the left, the raw type frequency from the search is listed; on the right, the percentage of the possible monosyllables that could be formed with that consonant-tone sequence that are *actually* words is given.

Table 3. *Lexical Type Frequency for Monosyllabic Native Thai Words.*

| Ons | M Tone | | L Tone | | F Tone | | H Tone | | R Tone | |
|---|---|---|---|---|---|---|---|---|---|---|
| $C_{else}$ | 490 | 31% | 167 | 10% | 368 | 23% | 242 | 15% | 321 | 20% |
| T | 242 | 44% | 134 | 24% | 138 | 25% | 13 | 2% | 29 | 5% |
| D | 53 | 39% | 36 | 26% | 43 | 31% | 0 | 0% | 5 | 4% |

There are noticeably fewer native Thai words that contain [+CG]-high and [+CG]-rising tone sequences. While there are some words that do contain this sequence, their number is low enough (less than 5.2%), creating a sharp contrast with the attested consonant-tone sequences (more than 10%). Results were similarly computed for the ORCHID corpus that were consistent with the results reported above in table 3.

### *3.1.2. Evidence from a Perceptual Experiment*

This section reports results from a judgment experiment that confirms that Thai speakers grammaticalize the consonant-tone gaps reported in the previous subsection [12]. Pairs of nonce words are presented aurally and speakers are asked to judge which of the two nonce words sounds more likely to be a Thai word. Nonce words are identified based on whether they satisfy all of the following three criteria: 1) They have a corpus frequency of zero in the ORCHID corpus; 2) they do not occur in [15]'s online Thai dictionary; 3) they do not occur in [14]'s appendices. Any monosyllable that meets all of these three criteria is taken to be a non-word of Thai.

Stimuli pairs are built using only minimal pairs, with the reported native lexical gaps in mind. There are two types of minimal pairs. In the first type, the stimuli are identical except for the tone; in the second type, the stimuli are identical except for the onset laryngeal specification. Test stimuli pairs always have one nonce word predicted to be dispreferred if a lexical gap in the *native stratum* is grammaticalized, with the other nonce word predicted to be grammatical. In addition to the test stimulus pairs, control comparisons were included to ensure that speakers did not simply have a general preference for low tone over high tone or for aspirated stops over unaspirated stops.

Stimulus pairs were formed using the full variation of onset place of articulation and vowel quality. Only CV: monosyllables were used. The Thai lexicon provides us with a total of 192 stimuli pairs where both members in the pair are nonce words. Thirty-two of these pairs were presented twice, with the order of presentation differing. A total of 224 stimulus pairs were used as a result.

The stimuli were recorded using a female native speaker of standard Thai spoken in Bangkok. Sixteen participants were recruited in the Bangkok region of Thailand by a native Thai speaker who was trained in theoretical Linguistics.

The results are summarized in Figure 1 below (from [12]:125 fig. 19); they confirm that all four onset-tone restrictions are grammaticalized in the native Thai lexical stratum. In the eight test comparisons, if the consonant-tone sequences are ungrammatical, participants should choose the

[1] There are 21 possible simple onsets and 17 possible complex onsets, for a total of 38 possible onsets. There are 9 monophthongal vowels and 3 diphthongs, for a total of 12 distinct vowel qualities. There are 5 tones, 2 vowel lengths and 9 possible codas: 38 onsets * 12 vowels * 5 tones * 2 vowel lengths * 9 codas = 41,040 possible monosyllables. However, glide codas occur with a restricted subset of vowels, resulting in a total of 32,110 total possible monosyllables.

"0" responses, (bottom of the chart). A response mean closer to "1" (top of the chart) indicates a preference for the hypothetically ungrammatical onset-tone sequence. If the participants responded randomly, then it is expected that the mean response score should be 0.5, indicated by the solid line.

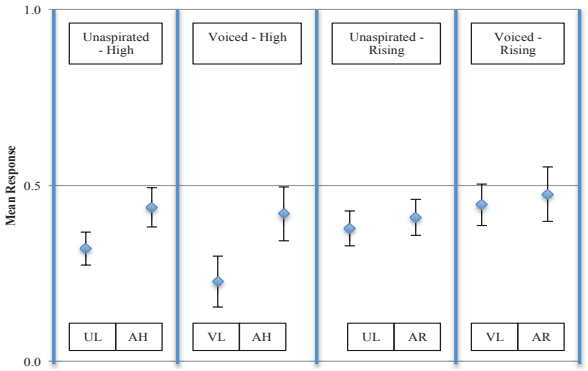



Figure 1: *Mean response scores in the judgment experiment.*

The *unaspirated-high, voiced-high* and *unaspirated-rising* sequences were all dispreferred in both comparisons varying tone and manner. The *voiced-rising* sequence was slightly dispreferred in comparisons varying tone, but not in comparisons varying manner though.

### 3.2. The Active Feature is [+CG]

This section offers evidence from an acoustic study in [11] that the consonant-tone restriction involves the feature [+CG], rather than [–SG], as posited by [9, 10]. The acoustic study searched for the presence of glottal constriction in the vowel immediately following a [+CG] onset consonant. F0 and spectral tilt were measured 10 ms after the onset of the vowel in order to confirm this. It is predicted that both F0 and spectral tilt should be significantly less if the preceding consonant is glottalized. This section reports only the spectral tilt results.

Three native speakers of Bangkok Thai pronounced a series of CV: stimuli whose tone and onset manner varied (only the vowel [a] was used) eight times each, in a random order. The stimuli were placed in a filler sentence with adjacent mid-tone words in stressed positions, to ensure no coarticulatory effects. The filler sentences of [12] was used. Onset consonants were bilabial stops ($p^h$, p, b, m) and glottals (ʔ and h). The recordings were done in a sound-proof booth.

The results showed that spectral tilt was significantly lower following unaspirated and voiced stops than it was following other stops. Figure 2 below shows the results for spectral tilt. Note that for all three speakers, the spectral tilt is significantly lower in vowels following [b] and [p] than for [$p^h$] and [m].

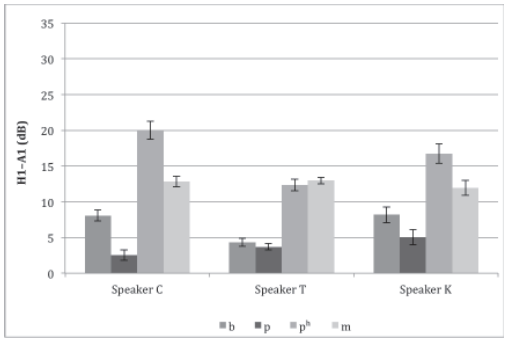



Figure 2: *Mean Spectral Tilt measurements for each speaker categorized by onset*.

This confirmed that unaspirated and voiced stops are produced with glottal constriction in Thai, and should thus be analyzed as [+CG], and not [–SG].

## 4. Phonological Analysis

Given the evidence in section 3, a new phonological analysis is outlined that utilizes two new constraints that refer to the tonal specification of the rightmost of two moras in a syllable; these constraints are defined below.

- *[+CG]-[H]μ2 – Incur one violation per H tone autosegment that is linked to the second mora in a syllable that has a [+CG] onset consonant.
- LIC-T-Rt – Assign one violation for a syllable associated with a tone, but whose rightmost mora is not associated to a tone (*HM, LM).

*[+CG]-[H]μ2 is *not* violated by [+CG]-falling tone sequences, but *is* violated by [+CG]-high tone and [+CG]-rising tone sequences. The two ungrammatical sequences share a common phonetic characteristic: They both have *late* H-tone targets, a fact that is reflected in the representations shown in Table 1 above. On the other hand, the falling-tone sequence involves an early H-tone target. If adjacency is evaluated based on the linear order of the moras with respect to the onset consonant, then the falling-tone sequence is the only one where the H is strictly adjacent to the [+CG] onset consonant. Yet, this is the only sequence involving an H tone that *is* grammatical. This situation can only be resolved under an analysis where locality is irrelevant.

As a result, it is argued that the onset-tone restrictions in Thai involve a sequence of a [+CG] onset followed by an H tone linked to the second mora in that syllable. A markedness constraint *[+CG]-[H]μ2 is introduced that is violated once per syllable whenever a [+CG] onset consonant occurs within a syllable whose second mora is linked to an H tone (following [12], it is assumed that all syllables in Thai are bimoraic). The constraint, *[+CG]-[H]μ2, is argued to be motivated in part by a universal tendency for pitch targets to be realized late in syllables [4, 18, 19]. The second mora can thus be seen as carrying the "head tone" of the syllable, and as such it is the relevant location in a constraint banning high tone with [+CG] onsets. This situation is illustrated below in Figure 3.

| | | |
|---|---|---|
| X | **H** | Autosegmental Tone Tier |
| \| | \| | |
| μ | μ | Mora |
| \| | \| | |
| $\mathbf{C}_{[+CG]}$ V | V | Segmental Tier |

Figure 3: *The ungrammatical onset-tone sequence in Thai unchecked syllables (*[+CG]-[H]μ2).*

The constraint, *[+CG]-[H]μ2 is not violated by CG-falling sequences, but it is violated by CG-high and CG-rising sequences. As such, it captures the pattern of onset-tone interaction accurately, mapping H tone inputs to HL tone on the surface. This is demonstrated in the tableau in Table 4 below for a hypothetical input with two H tones (I assume M

to be phonologically toneless; this represents a mora that is unlinked to any tone here).

Table 4. *Ranking of* *[+CG]-[H]μ2

| | /pá: HH/ | *[+CG] -[H]μ2 | MAX[H] | * L | *2TONES | ALIGN -R |
|---|---|---|---|---|---|---|
| | a. pá: HH | *! | | | * | |
| | b. pá: MH | *! | * | | | |
| ☞ | c. pâ: HL | | * | * | * | * |
| | d. pă: LH | *! | * | * | * | * |
| | e. pa: MM | | **! | | | |

Candidates (a), (b) and (d) where the H tone is linked to the second mora all fatally violate *[+CG]-[H]μ2. The remaining candidates (c) and (e) avoid this fatal violation. However, candidate (e) incurs an extra fatal violation of MAX[H]. As a result, candidate (c) is optimal. The ranking that must hold for Thai then is *[+CG]-[H]μ2, MAX[H] >> *L, *2TONES, ALIGN-R.

The constraint LIC-T-Rt is used to rule out one additional troublesome candidate however. An HM tone sequence offers a way to avoid a fatal violation of both *[+CG]-[H]μ2 and MAX[H]. Similar to the *[+CG]-[H]μ2 constraint, LIC-T-Rt is one that references the rightmost mora. It captures the fact that if there is going to be a single tone, it is relatively more marked to align this tone on the left side of the syllable than on the right side. The fact that tonal targets tend to be realized late in syllables cross-linguistically is the main impetus for tonal alignment in the first place [18, 20:83, 147]. This constraint is vacuously satisfied by toneless syllables (mid tone) and is satisfied by contour tones, since the second mora is associated with a tone.

Unlike the alignment constraint, ALIGN-R, LIC-T-Rt is able to distinguish between candidates (a) and (b) in Table 5 below, preferring an HL sequence over HM.

Table 5. *Ranking of* LIC-T-Rt

| | /pá: HM/ | ALIGN-R | LIC-T-Rt | *L | *2TONES | ALIGN-L |
|---|---|---|---|---|---|---|
| | a. pá: HM | * | *! | | | |
| ☞ | b. pâ: HL | * | | * | * | * |

A regular alignment constraint could not distinguish between the HL and HM sequence, since both candidates have an H tone misaligned with the right edge. However LIC-T-Rt is vacuously satisfied by candidate (b), since its rightmost mora is associated with a tone (L); candidate (a) however violates LIC-T-Rt since it has a tone (H), but there is no tone on the rightmost mora.

## 5. Conclusion

This paper has outlined recent work by [12] that suggests previous phonological accounts of consonant-tone sequence restrictions in Thai are based on false assumptions. First, as mentioned, it accounts for a previously undocumented [+CG]-rising-tone ban. Second, it outlines acoustic findings that imply [+CG] and not [-SG] is the active feature in the consonant-tone restriction.

The phonological account features two new constraints, *[+CG]-[H]μ2 and LIC-T-Rt that refer to the rightmost mora in a syllable. *[+CG]-[H]μ2 places a restriction on H tones linked to the second mora following a [+CG] onset. LIC-T-Rt is similar to an alignment constraint, but only applies to the rightmost mora in syllables that contain some tone. This preference for the rightmost mora is explained by the fact that tonal information is often preferentially carried late in syllables. As a result, the second of two moras can be treated as the head mora in phonology. This headship thus licenses this second mora as a special position, with markedness constraints like *[+CG]-[H]μ2 and LIC-T-Rt that can reference it explicitly.

## 6. Acknowledgements

I would like to thank Shigeto Kawahara, Akinbiyi Akinlabi and Bruce Tesar for their assistance in this research. In addition, Seunghun Lee has been very helpful with suggestions and comments.

## 7. References

[1] Abramson, A., "The vowels and tones of standard Thai: Acoustical measurements and experiments", International Journal of American Linguistics 28, 1962.

[2] Abramson, A., "The tones of central Thai: Some perceptual experiments", in J. Harris & J. Chamberlain [Eds], Studies in Tai Linguistics, 1-16, Central Institute of English Language, 1975.

[3] Abramson, A., "Static and dynamic acoustic cues in distinctive tones", Language & Speech 21:319-325, 1978.

[4] Cutler, A. & Chen, H., "Lexical tone in Cantonese spoken-word processing", Perception & Psychophysics 59(2):165-179, 1997.

[5] Gandour, J., "Consonant types and tone in Siamese", University of California Working Papers in Phonetics 27:92-117, 1974.

[6] Gandour, J., "Perceptual dimensions of tone: Evidence from Cantonese", Journal of Chinese Linguistics 9:20-36, 1981.

[7] Gandour, J., "Tone perception in far eastern languages", Journal of Phonetics 11:149-175, 1983.

[8] Kasuriya, S., Sornlertlamvanich, V., Cotsomrong, P., Kanokphara, S., Thatphithakkul, N., "Thai speech corpus for speech recognition", Proceedings of Oriental Committee for the Co-Ordination and Standardization of Speech Databases and Assessment Techniques", Singapore, 2003.

[9] Lee, S., "Consonant-tone interaction in optimality theory", PhD Dissertation, Rutgers University, 2008.

[10] Lee, S., "Tonal OCP and consonant-tone interaction in Thai", Journal of Southeast Asian Linguistics Society 4:61-76, 2011.

[11] Morén, B. & Zsiga, E., "The lexical and post-lexical phonology of Thai tones", Natural Language & Linguistic Theory 24:113-178, 2006.

[12] Perkins, J., "Consonant-tone interaction and laryngealization in Thai", Conference presentation at the Southeast Asian Linguistics Society XXI, Kasetsart University, Bangkok, Thailand, 2011.

[13] Perkins, J., "Consonant-tone interaction in Thai", PhD Dissertation, Rutgers University, 2013.

[14] Ruangjaroon, S., "Consonant-tone interaction in Thai: An OT analysis", Taiwan Journal of Linguistics 4:1-66, 2006.

[15] Slayden, G., "IPA query results via AJAX" from thai-language.com, accessed on 12 Mar 2013.

[16] Tumtavitikul, A. "Consonant onsets and tones in Thai", PhD Dissertation, U. Texas-Austin, 1992.

[17] Tumtavitikul, A. "Perhaps, the tones are in the consonants?", Mon-Khmer Studies 23:11-41, 1993.

[18] Xu, Y., "F0 peak delay: When, where, and why it occurs", in J. Ohala [Ed], International Congress of Phonetic Sciences, 1881-1884, 1999.

[19] Xu, Y., "Understanding tone from the perspective of production and perception," Language & Linguistics 5:757-797, 2004.

[20] Yip, M., "Tone", Cambridge; New York: Cambridge University Press, 2002.